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The Geology of the Mid Mannville Subgroup
in the West-Central Lloydminster
Heavy Oil Trend, Alberta.

by

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Abstract

The mid Mannville sequence in west-central Lloydminster, Alberta, was deposited in a shallow semi-enclosed, brackish embayment on the western side of the Wainwright Ridge. The development of the sequence in this area was controlled by; the topography of the sub-Cretaceous unconformity; eustatic sea-level changes; and the regional sediment supply.

Three major lithofacies were developed in the west central Lloydminster area.

1. A mudstone/sandstone lithofacies deposited in a tidally influenced, brackish, lagoonal/estuarine setting. This makes up the RL and GP units and also occurs at the base of the Lloydminster and Sparky units.
2. Well-sorted wave-dominated coarsening-upward sandstone sheets deposited on a marine shoreface. These sheet sandstones are present in the upper part of the Lloydminster and Sparky units.
3. Poorly-sorted, fining-upward, feldspathic sandstone channels with associated overbank and coal swamp deposits which were formed in an upper estuarine, tidally influenced fluvial setting. These channels occur in the GP and Sparky units.

The mid Mannville sequence in west central Lloydminster differs from the mid Mannville in east-central and south Lloydminster, which was deposited on the eastern side of the Wainwright Ridge. The brackish lithofacies that predominate west of the Ridge are not as extensively developed to the east and south. The GP unit in particular entirely loses its marine character in west-central Lloydminster. Lower shoreface marine sediments are common in south Lloydminster, but are absent in the west.

The Viking-Kinsella field is the only field developed in west-central Lloydminster. It is one of the few Lloydminster fields in Alberta whose origin is not directly related to the structure of the sub-Cretaceous unconformity. It is a result of the incision of the Sparky B reservoir unit by both mid and upper Mannville fluvial/estuarine channel systems. Recently a new pool was discovered in west-central Lloydminster within an anticlinal structure formed by drape over a positive feature on the sub-Cretaceous unconformity surface.

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Introduction

The major feature controlling deposition of the lower and mid Mannville units in east-central Alberta was the Wainwright Ridge. This northwest to southeast trending topographic ridge had a profound influence upon the basin drainage, the extent of the marine transgressive-regressive events, and the local and regional sediment supply (O'Connell, 1985). The major Lloydminster heavy oil deposits are located to the east of, or as in the case of the Wainwright field, on the crest of the ridge (figure 1). The only major Lloydminster field developed to the west of the ridge is the Viking-Kinsella field in township 48, ranges 8 and 9 west of 4.

This study developed from an examination of the reservoir and associated units in the Viking-Kinsella field area (township 48, ranges 8 and 9 w4). Production in this field is from the Sparky unit. This unit is poorly understood and little work has been done to relate it to the overall development of the Mannville Group within which it occurs. This report provides a thorough description of the mid Mannville subgroup in west-central Lloydminster, it shows how the sequence in this area relates to mid Mannville sequences in east and south Lloydminster and provides an environmental reconstruction during the time of its deposition. The local geology of the Viking-Kinsella field area, the distribution of hydrocarbons and the trapping mechanism are described and their development is related to regional geological trends.

A total of 20 townships are included in this study, from township 46 to 49, ranges 7 to 11 w4. In total 609 wells were examined within this area; their distribution is shown in figure 2. Cores from 23 wells in this area were examined along with a further 7 wells from the central Lloydminster region.

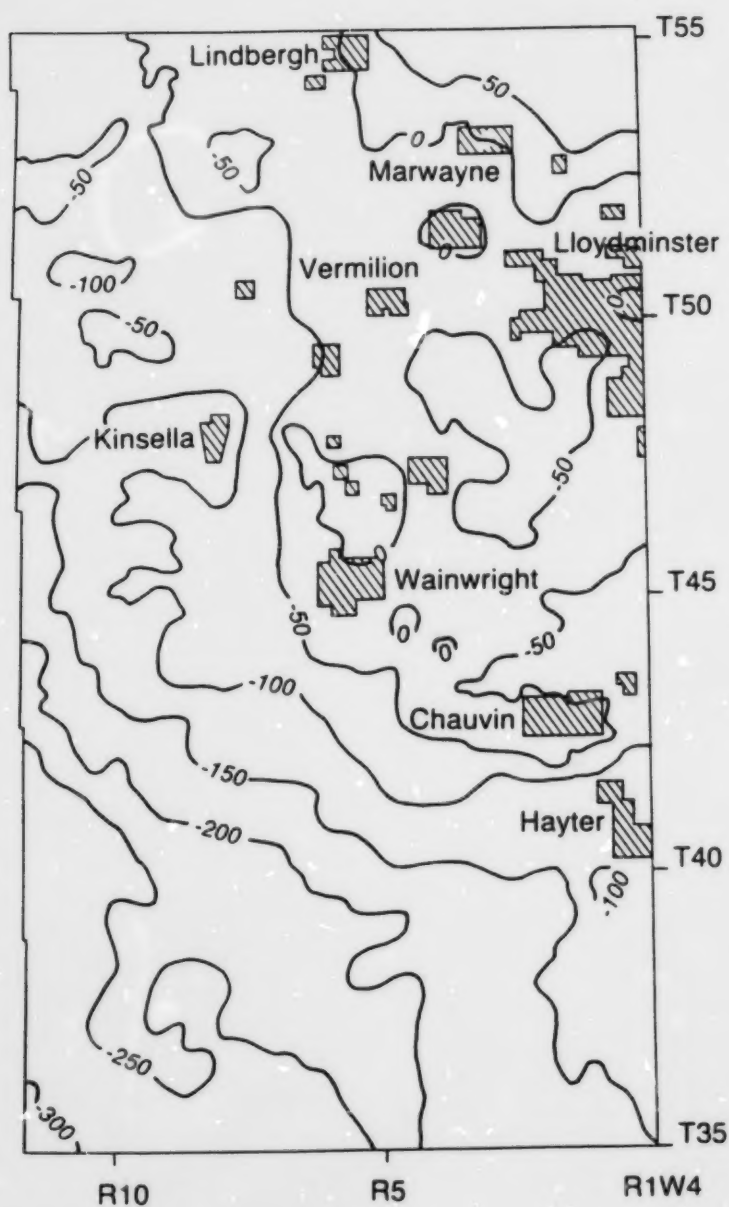


Figure 1 Structure of the sub-Cretaceous unconformity with the location of the main Lloydminster fields.

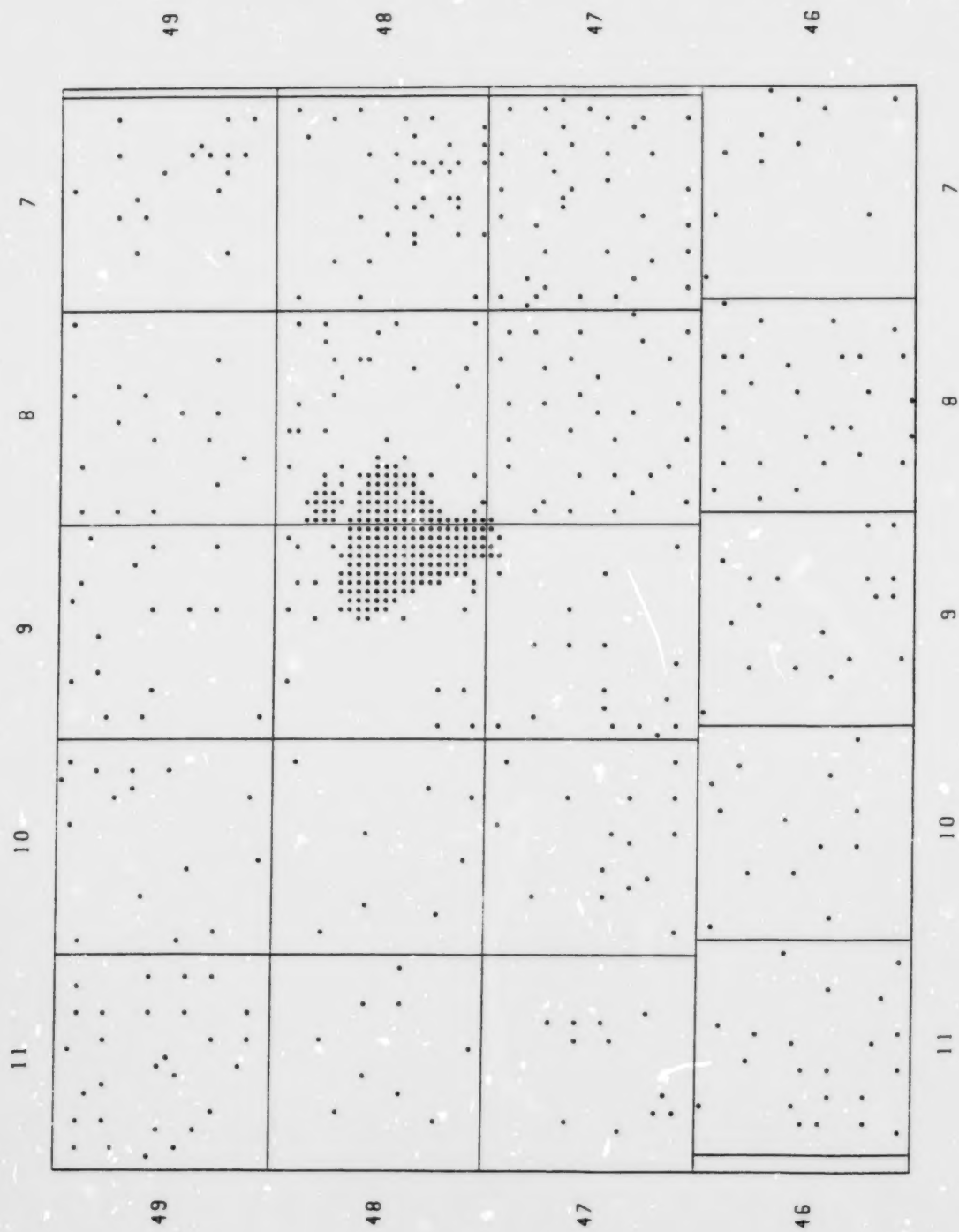


Figure 2 Distribution of wells in the study area.

These cores are listed in Appendix 1.

General Overview of the Mannville Group

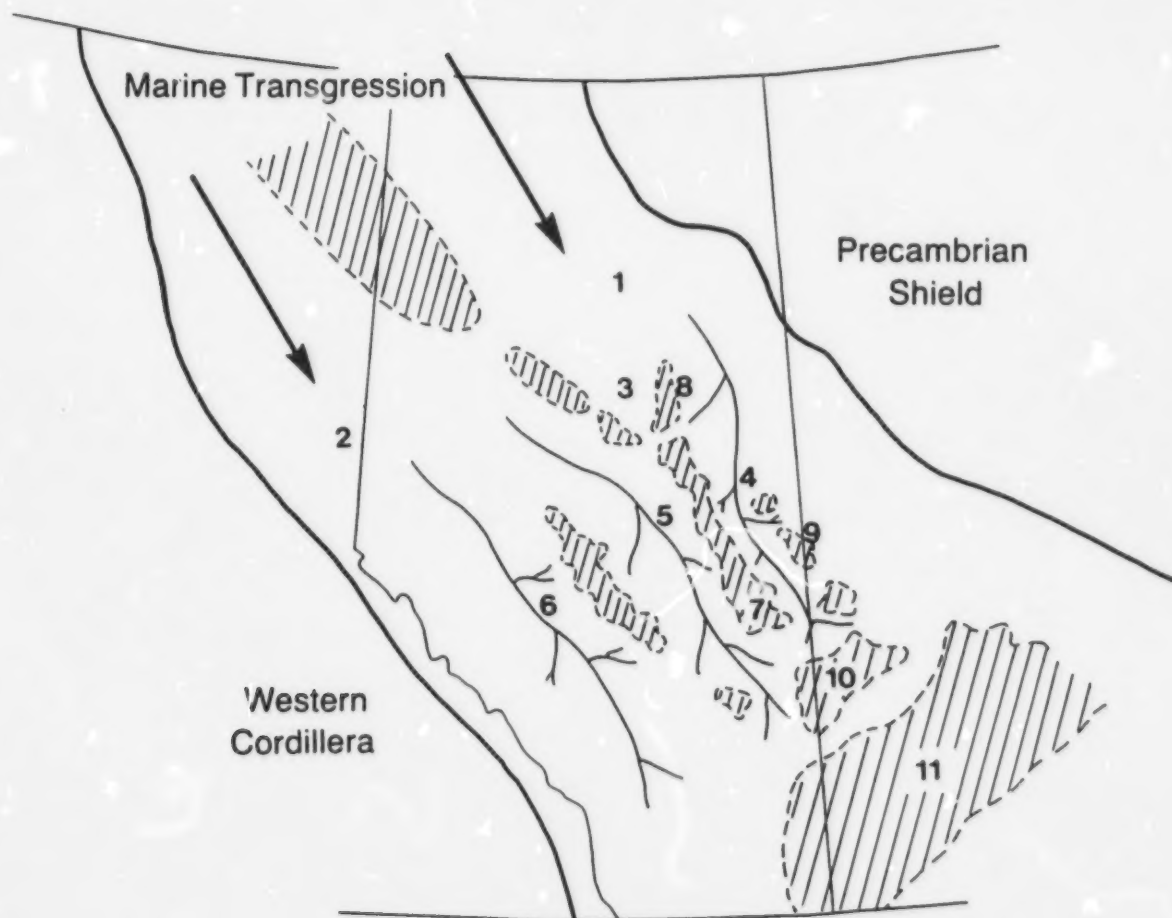
In the Lloydminster area the Mannville consists of three subgroups, the lower, middle and upper, which are divided into a number of informally designated units (figure 3). The sequence was deposited in a broad, shallow basin that opened towards the northwest. The general outlines of this basin and its internal topography are shown in figure 3a. The lower Mannville consists of a fluvial valley-fill sequence known as the Dina, which typically consists of a thick, blocky sandstone formed by amalgamated channel sequences. This is overlain by the Cummings, which is transitional from flood plain deposits to estuarine and shallow marine sandstones and mudstones. The base of the mid Mannville Subgroup is defined as the base of the first marine Cummings sandstone.

The mid Mannville subgroup was examined in the south Lloydminster area, east of the Wainwright Ridge by O'Connell (1985). It was determined that the sequence was deposited by five distinct marine transgressive-regressive events. The sequence consists of four shallowing-upward, regressive marine units, each passing from offshore mudstones into shoreface sandstones capped by lagoonal and flood-plain deposits. (The fifth marine unit, the Cummings, is poorly developed or absent throughout the south Lloydminster area). These transgressive deposits are rarely preserved except at the base of the Sparky unit, where they are found in topographically low areas. Between the Lloydminster and Rex marine transgression-regressions there was a period of relative stillstand in which a brackish shoreline to shallow marine sequence was built up. The sequence was named the RL unit by O'Connell (1985).

AGE		Athabasca	Cold Lake	Lloydminster			
Lower Cretaceous	Albian	La Biche Fm	Colorado Grp	Colorado Grp			
		Pelican Fm			Viking Fm	Viking Fm	
		Joli Fou Fm			Joli Fou Fm	Joli Fou Fm	
		Mannville Grp	Grand Rapids Fm	Mannville Grp	Mannville Grp	Colony McLaren Waseca	Upper
			Clearwater Fm			Lower Grand Rapids	Sparky GP
	Wabiskaw Mbr		Clearwater Fm			Rex Lloydminster Cummings	
	McMurray Fm		McMurray Fm			Dina Fm	Lower
	Aptian and Older						
Pre-Cretaceous		Devonian					

(After Kramers, 1984)

Figure 3 Mannville stratigraphy, east-central and northern Alberta (modified after Kramers, 1984).



- | | |
|-------------------------|----------------------------|
| 1. Athabasca Basin | 7. Wainwright High |
| 2. Gething Basin | 8. Grosmont High |
| 3. Wabasca Sub-Basin | 9. Lindbergh High |
| 4. St. Paul Channel | 10. North Battleford High |
| 5. Edmonton Channel | 11. Swift Current Platform |
| 6. Spirit River Channel | |

Figure 3a Approximate Mannville paleogeography at the Aptian-Albian boundary showing basin outlines and the topographically high areas with inferred fluvial drainage (after McLean and Wall, 1981; Stott, 1982; McLean and Putnam, 1983; Ranger 1984).

The coastal depositional setting envisaged for the mid Mannville in south Lloydminster is shown in figure 4. In this setting the sand units formed barriers, small deltas or strandplains on a wave dominated shoreline. Three major factors influenced the deposition of the sequence. (1) Sea-level variation; the extent and duration of each invasion controlled the distribution and development of the units. (2) The sub-Cretaceous unconformity; this created a resistant topography which divided the area into small basins and acted as a barrier to marine invasion and the free movement of sediment within the region. It located the position of the coastal systems and influenced the drainage patterns. (3) Sediment supply. This was locally variable and was a major influence upon the development of the units. The development of continuous sheet sandstones depended on the maintenance of a stable sediment supply, usually from regional longshore sources. When these sources were not available, patchy and irregular sand bodies developed.

Under the influence of these factors the mid Mannville developed as a series of thin top-truncated regressive marine units separated by brackish shoreline and floodplain deposits. Each regressive unit was subsequently incised by fluvial and shoreline channel systems developed during sea level low-stands. The distribution of the lower units was limited by the exposed subcrop of the sub-Cretaceous unconformity, the upper units were influenced by the low relief topography inherited from the now buried unconformity.

Various authors have interpreted mid Manville units as being tidal deposits. Burnett and Adams (1977) proposed that the Sparky unit in the central Lloydminster area was deposited as offshore bars by tidal currents on a marine shelf. Fuglem (1970) proposed that Sparky deposition took place in tidal

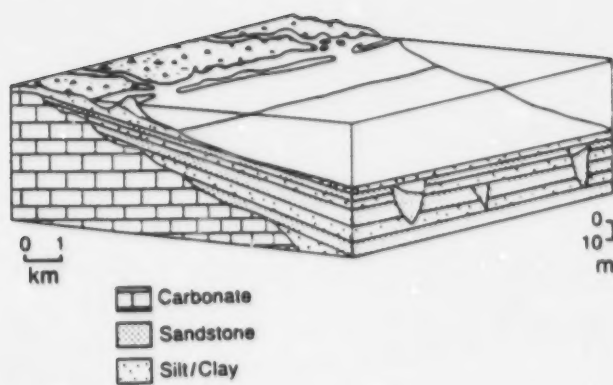


Figure 4 Generalized mid Mannville depositional setting in south Lloydminster.

flats, on the basis of micropaleontology which indicated the presence of restricted marine environments. McCallum (1979), from log analysis, envisaged a tide dominated shoreline setting in which barrier bars are deposited by longshore currents and incised by accompanying tidal channel networks. Zaitlin and Shultz (1984) investigated the Lloydminster unit in the Senlac area in Saskatchewan. They interpreted the unit as being tidally deposited within an estuary. This estuary was contained within an embayment created by the topography of the sub-Cretaceous unconformity. Their field area was a little over a township in size. Wilson (1984), working in the Tangleflags area in Saskatchewan, interprets the Lloydminster as a tidal inlet deposit.

The upper Mannville subgroup in the Lloydminster area consists of intermixed floodplain and brackish shoreline deposits. These were deposited by fluvial systems flowing eastwards into a brackish marine embayment in east central Lloydminster. The sequence is notable for its thick amalgamated channel deposits (Wightman et al, 1987).

The Geology of the West Central Lloydminster Area

The Sub-Cretaceous Unconformity

A map of the present day structure of the unconformity in west-central Lloydminster is shown in figure 5. The dominant topographic feature in the area is the western edge of the north-south trending Wainwright Ridge in range 7w4. This has a maximum elevation of 10m above sea-level in township 47. Most of the central part of the area is 90m below sea-level in elevation with a minimum elevation of 170m below sea-level. This topography is reflected in the total thickness of the Mannville Group (figure 6). The Mannville Group thins to less than 100 metres over the Wainwright Ridge in range 7w4, townships 46, 47 and 48, and also over the isolated topographic features centered in township 47 range 10w4 and township 49 range 11w4. In contrast, the total Mannville thickness in the basinal parts of the area averages between 140m and 170 m.

The Lower Mannville

The Dina unit is present in the topographically low parts of the area. It is recognized by a blocky sandstone profile, as shown in an east-west cross section west-central Lloydminster (figure 7). This is overlain by the Cummings unit. Since there is no lower Mannville core in the area, and log characteristics of the Cummings are not diagnostic, the Cummings marine/non-marine transition cannot be determined. The top of the Cummings is marked by a coal unit up to 4m thick. This is the thickest Mannville coal in this area and for convenience its top is taken to be the base of the mid Mannville.

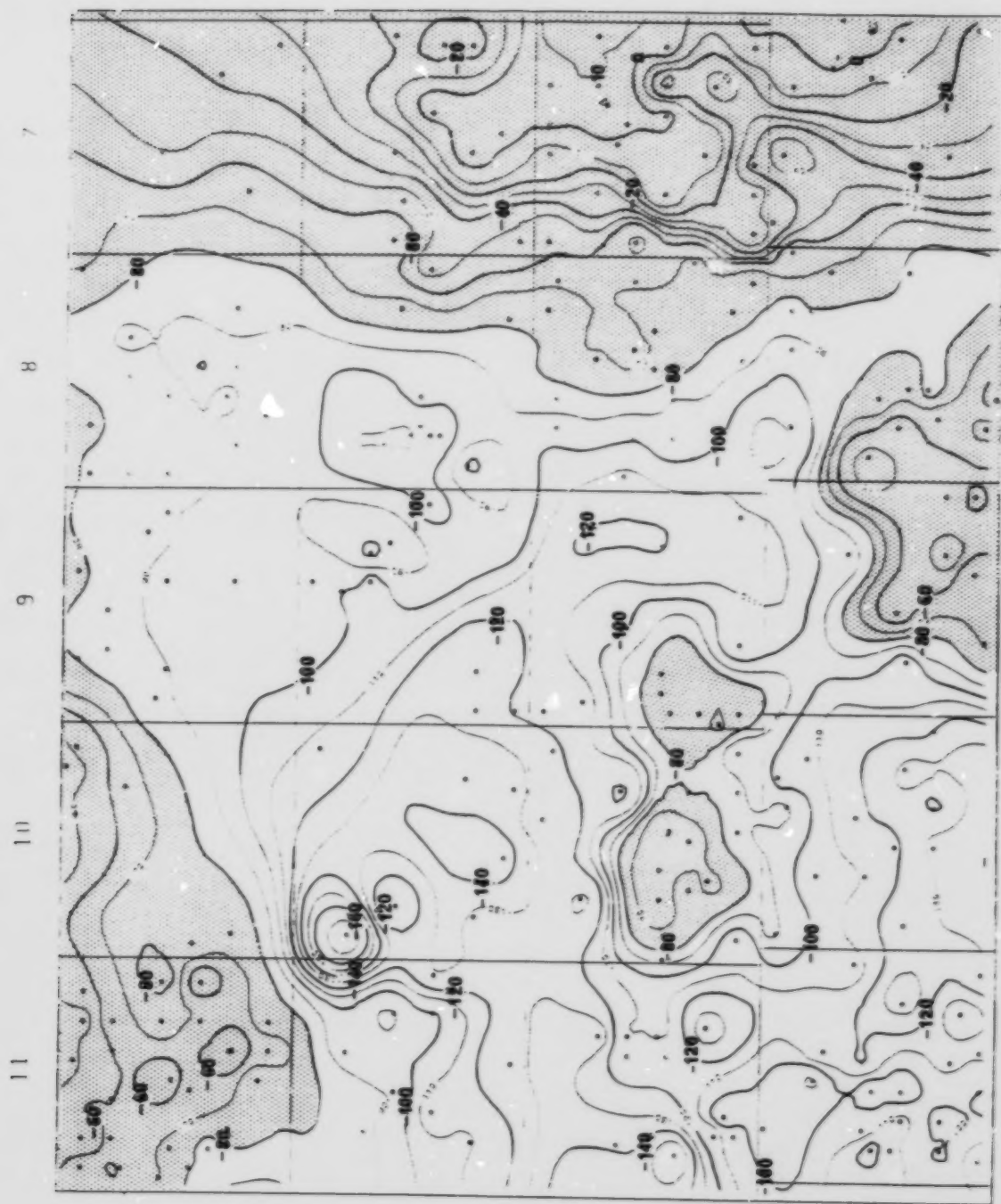


Figure 5 Structure of the sub-Cretaceous unconformity in west-central Lloydminster. Contour interval is 10 metres. The shaded area is higher than -80 metres. Depths are relative to present day sea-level.

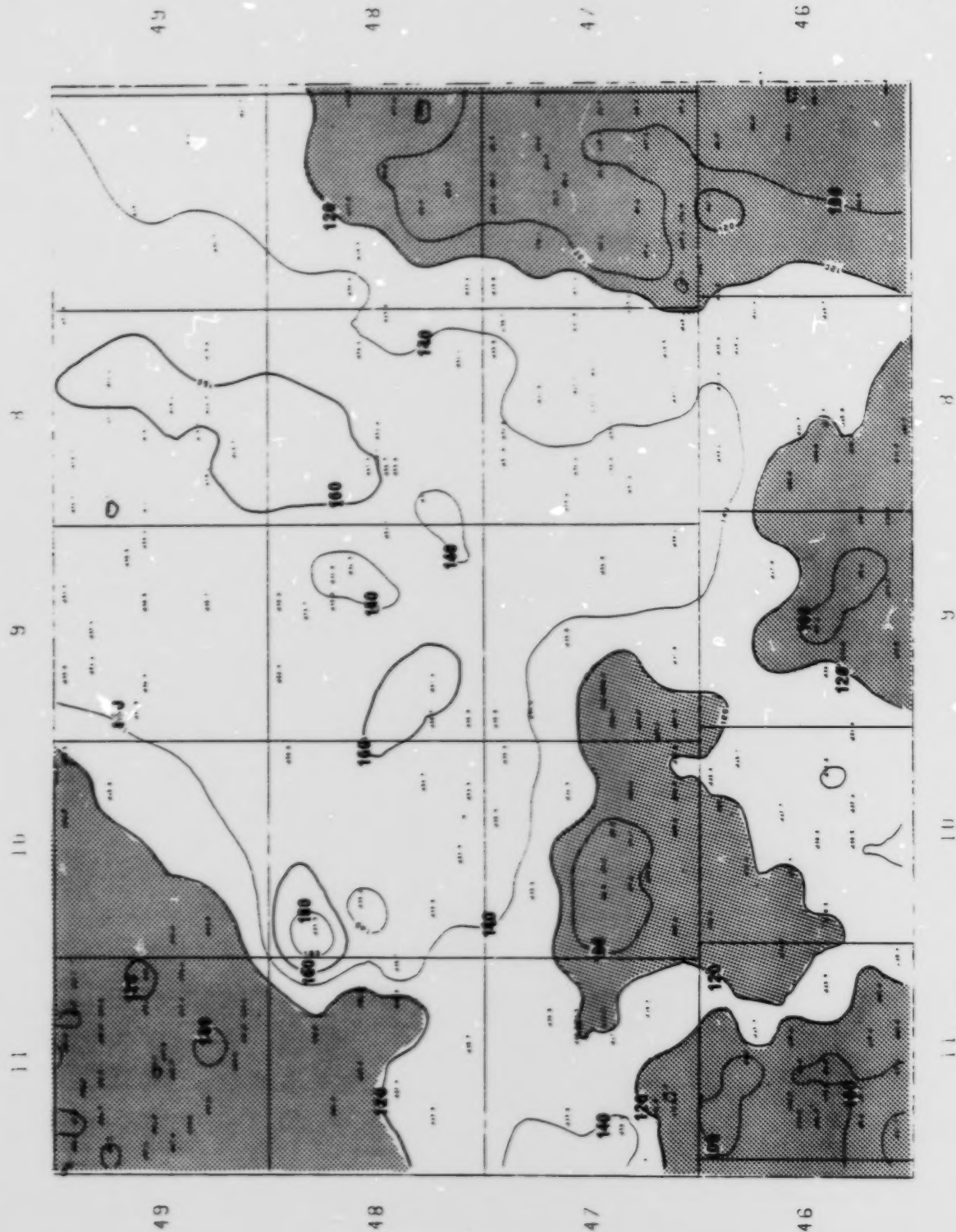


Figure 6 Total thickness of the Mannville Group in west-central Lloydminster. Contour interval is 20 metres. Area less than 120m thick are shaded.

The Mid Mannville

The mid Mannville consists of four distinct units; the Lloydminster; the RL-Rex; the GP; and the Sparky. A well log of a typical mid Mannville sequence is shown in figure 8.

Description of Mid Mannville Lithofacies

Three distinct lithofacies occur within this sequence in west-central Lloydminster.

- I. Brackish-bay mudstones and sandstones.
- II. Wave-dominated shoreface sandstones.
- III. Channel sandstones.

I. Brackish-bay mudstones and sandstones.

Description:

Sequences consisting of mudstone and interlaminated mudstone-sandstone make up the majority of the RL and GP units and also occur in the lower parts of the Lloydminster, and Sparky units. They consist of dark grey, often highly carbonaceous mudstones containing zones of interlaminated, current-rippled sandstone, forming flaser and lenticular bedding, often with isolated sandstone lenses or 'starved ripples' (figures 21 and 21a(i)). Thinly interlayered parallel 'pinstriped' sandstone and mudstone layers occur and wave rippled sandstone lenses are common. Syneresis structures are also abundant (figure 16 iii). Zones of shale up to 1m thick with little bioturbation and rich in siderite are common throughout the sequences. Intensely bioturbated mudstones are present, underlying and sometimes interbedded with, the interlaminated mudstone/sandstone sequences. Due to bioturbation within these mudstones all

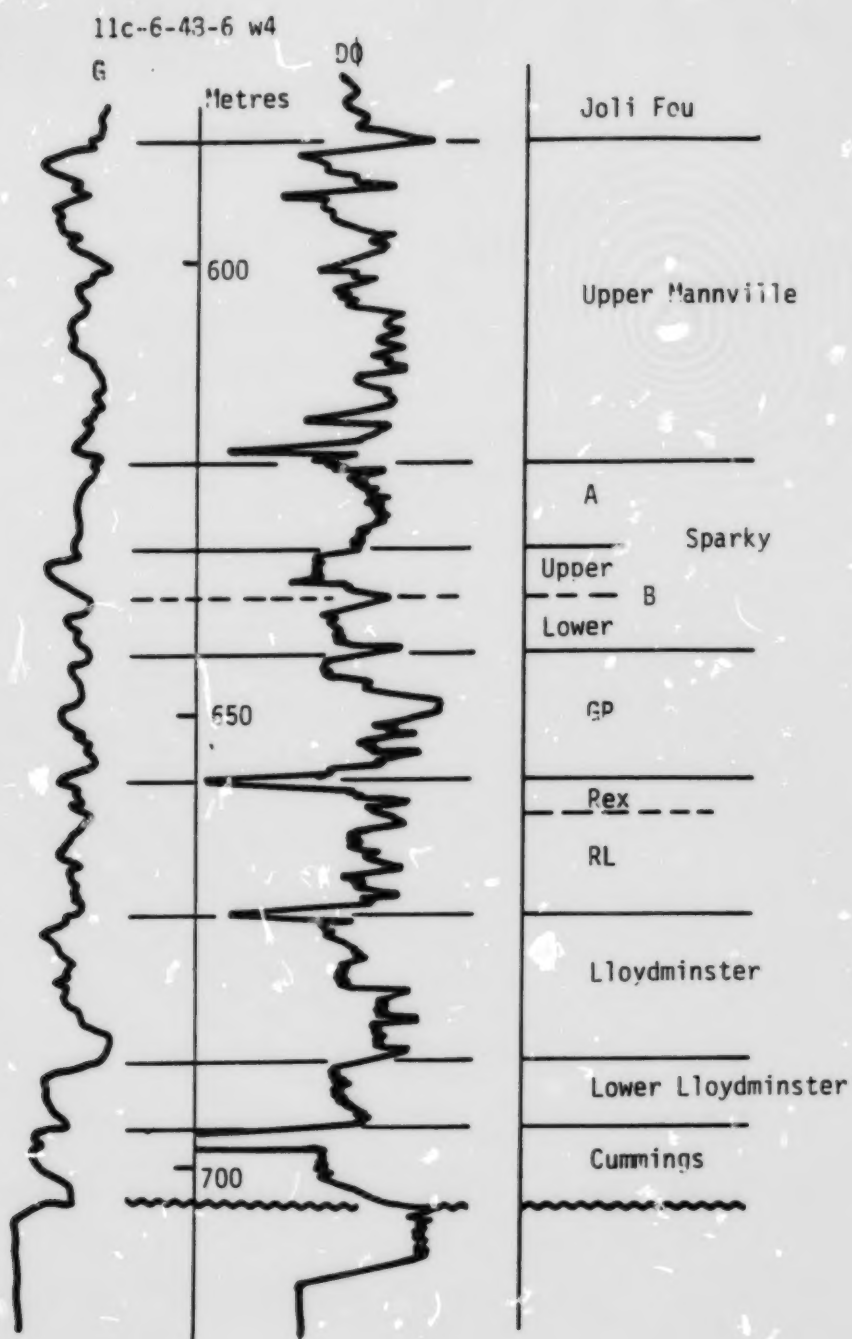


Figure 8 Representative Mannville well log. The Lower Mannville Dina Unit and much of the Cummings Unit are absent.

primary structure has been obliterated (figure 23 (ii)) and only trace fossils such as small sandstone-filled burrows of Planolites and Chondrites are distinguishable.

The ichnofauna in these sequences consists mainly of Skolithos, Teichichnus, Planolites, Chondrites and Gyrolithes. Palynological analysis (Appendix 2) shows that there is a moderate to low plankton species diversity with abundances of a few species types.

Sandstone units up to 8m thick are present in the RL and GP units. They occur within the interlaminated mudstone-sandstone sequences as sharply bounded fine to very-fine grained sandstones with occasional coarse grained laminae. High-angle cross-bedding, planar-bedding and large-scale climbing ripples are common in these sandstones (figure 17). The characteristic structure within the sandstones is parallel twinned mud couplets separating sands that are often current-rippled (figures 21a and 25(ii)). This gives a 'pinstriped' appearance to the sand sequence. The mud couplets occur as flat laminae or within low-angle and trough cross-bedding structures. Muddy interbeds up to 5 cm thick occur, often containing syneresis structures. Burrowing is rare with the ichnofauna consisting of vertical forms such as Skolithos and Teichichnus.

Interpretation:

This lithofacies appears to have formed in a brackish, tidally influenced environment in which there was restricted marine circulation accompanied by a mixing of fresh and salt water. A brackish environment is indicated by; the presence of syneresis structures (Plummer and Gostin, 1981); an ichnology characteristic of a mixed Skolithos-Cruziana ichnocoenosis (Eckdale *et al.*

1984); and a limited planktonic diversity common in restricted, marine influenced environments (Singh, pers. comm.). The interbedded sandstone/mudstone lithologies in these sequences are characteristic of tidal environments in which the alternating energy levels which deposit the interlaminated sandstones and mudstones are directly related to tidal rhythm (Reineck and Singh, 1980). The genesis of tidal bedding in the sandstones is due to the varying degree of current turbulence during each tidal phase. Sand is deposited by both flood and ebb currents, and mud is deposited during stand-still phases of high and low tides (Kreisa and Moiola, 1986). When sand and mud components are both available in the environment, the result is sandstone/mudstone couplets. Where little mud is available the interlayering is less distinct. Because bedforms persist throughout many tidal cycles, sandstone/mudstone couplets are seen within medium- to high-angle bedforms and troughs (figure 17 (i) and 25 (ii)). The presence of mud-layer couplets are diagnostic of tidal environments and facies. More specifically they occur in subtidal settings and cannot occur in the intertidal zone (Visser, 1980).

II. Wave dominated shoreface sandstones.

Description:

These occur in the Lloydminster and the Sparky B units. They consist of well sorted, quartzose, very fine- to medium-grained, coarsening-upward sandstones in which the dominant structures are planar, low-angle and hummocky cross-stratification and wave ripples (figure 12). The ichnofauna consists of Skolithos, Teichichnus, Diplocraterion and Chondrites. Bioturbation frequently obscures all of the primary sedimentary structures giving a mottled appearance to the sandstone (figure 25 (iii)). There is a mixed mudstone/sandstone transition zone up to 2m in thickness, at the base of these sandstone units.

Both current and wave ripples are present, and, occasionally, remnant tidal bedding structures are present with the bed tops often reworked into wave ripples (figure 25 (ii)). Mudstone interbeds up to 5 cm thick are often present, and these frequently contain syneresis structures. Palynology from these mudstones (Appendix 2) shows a more diverse plankton assemblage than that seen in the type I brackish/estuarine sequences. Megaspores are also present in the mudstones and are considered to be an indicator of proximity to a continental environment.

Interpretation:

Type II lithofacies were deposited in a marine shoreline environment open to wave influences. These have overwhelmed the tidal currents which are dominant in the semi-enclosed estuarine environment. The ichnofauna is still within the Skolithos-Cruziana assemblage zone while the plankton indicate a more open marine circulation (Singh, pers. comm.).

Type III Channel Sandstones.

Description:

Sandstone channels up to 15 metres thick occur in the GP and Sparky units. These channels have sharp erosional bases and fine upwards from coarse- and medium-grained sandstones at the base to fine- to very fine-grained sandstones, siltstones and mudstones at the channel top. These poorly sorted sandstones are highly feldspathic and contain zones that are indurated due to calcite cementation. A progression in sedimentary structures occurs from high- to medium-angle cross-bedding upwards into horizontal-lamination and current-ripples. Mudstone couplets may or may not be present. Burrowing is invariably absent from these channels and the overlying mudstones, but the channels often

contain large amounts of carbonaceous debris.

Interpretation:

These channels were formed in a fluvial- to upper- estuarine environment. The characteristic fining-upward sequence and the vertical sequence of sedimentary structures indicates lateral accretion within a point bar. Tidal influence within the meandering fluvial system gives rise to sandstone and mudstone couplets on the lateral accretion surfaces (Smith, in press). Calcite cementation is an indicator of a poorly sorted sandstone rich in chert fragments derived from the unconformity ridges. This relationship was noted in south Lloydminster by O'Connell (1985) who showed that the calcite is derived from carbonate material from the same source. Calcite cementation is not encountered within the well-sorted quartzose shoreline sandstones from which this material was removed.

Description of the Mid Mannville Units

The Lloydminster

The Lloydminster extends from the top of the Cummings coal to the top of the main Lloydminster sandstone, which throughout most of the area is marked by a coal unit. This coarsening-upward, mudstone-sandstone unit forms a continuous sheet throughout the area. The total thickness of the unit (figure 9), averages between 15m and 20m except in the area overlying the sub-Cretaceous ridge in range 7w4, townships 46 and 47, where it is less than 10m thick. An isopach of just the Lloydminster sandstone (figure 10) shows that it is thickest in the central, basinal part of the area and in the northeast where it is up to 16m thick. It thins rapidly to the west, and in range 11 w4 there is only between 0 and 4m of sand in the unit. It thins in a similar manner over the ridge in range 7 w4.

Two cross-sections illustrate the north-south and east-west variations within the Lloydminster unit. Figure 11 is a north-south section parallel to the depositional strike of the sand sheet and shows the coarsening-upward shale-sandstone unit and overlying coal zone. The east-west section, figure 7, shows how the sand sheet seen in range 7w4 becomes muddier to the west while still retaining, in ranges 10 and 11 w4, most of its overall thickness and coarsening upward profile.

No Lloydminster core has been recovered from the study area. The nearest available core is in the Wildmere field area in township 47 ranges 4 and 5 w4. In certain areas the Lloydminster sandstone can be traced continuously across the Wainwright Ridge from west-central Lloydminster to east-central



Figure 9 Isopach map of the Lloydminster Unit. Contour interval is 5 metres.

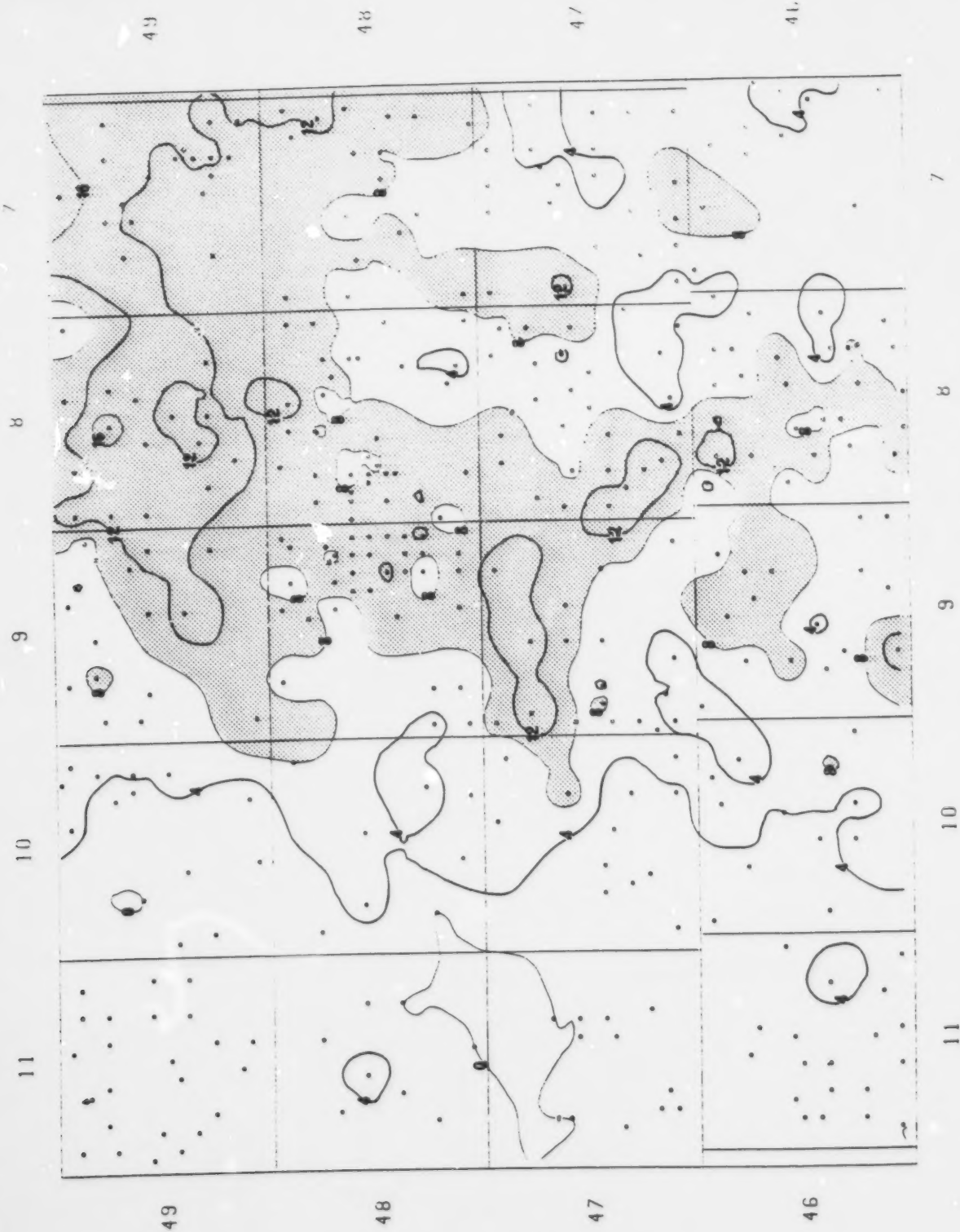
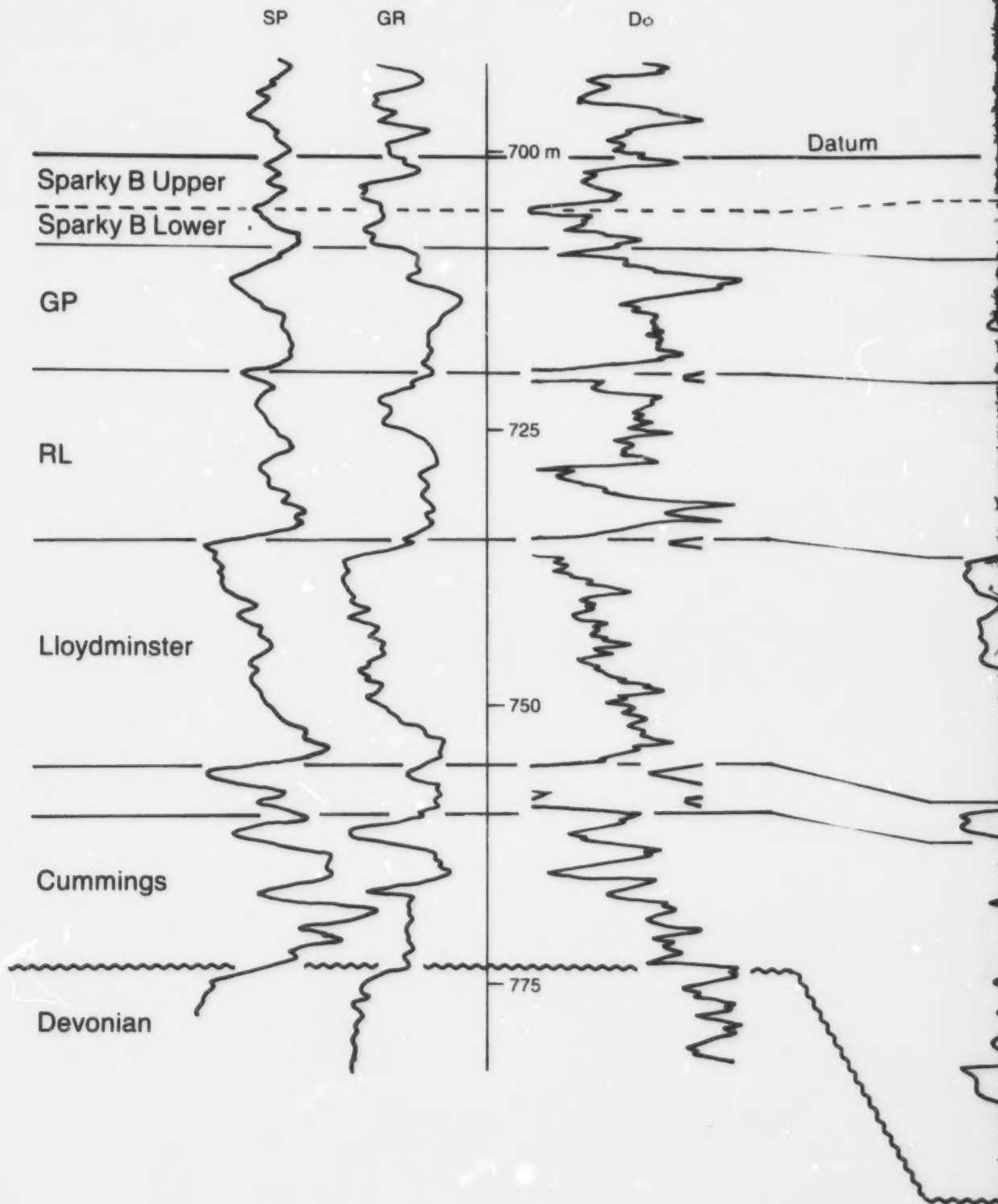


Figure 10 Isopach map of the Lloydminster Sandstone. Contour interval is 4 metres. Sandstones greater than 8 metres in thickness are shaded.

14-9-46-8W4



W4

15-5-47-8W4

10-7-48-8W4

6B-34-48-8W4

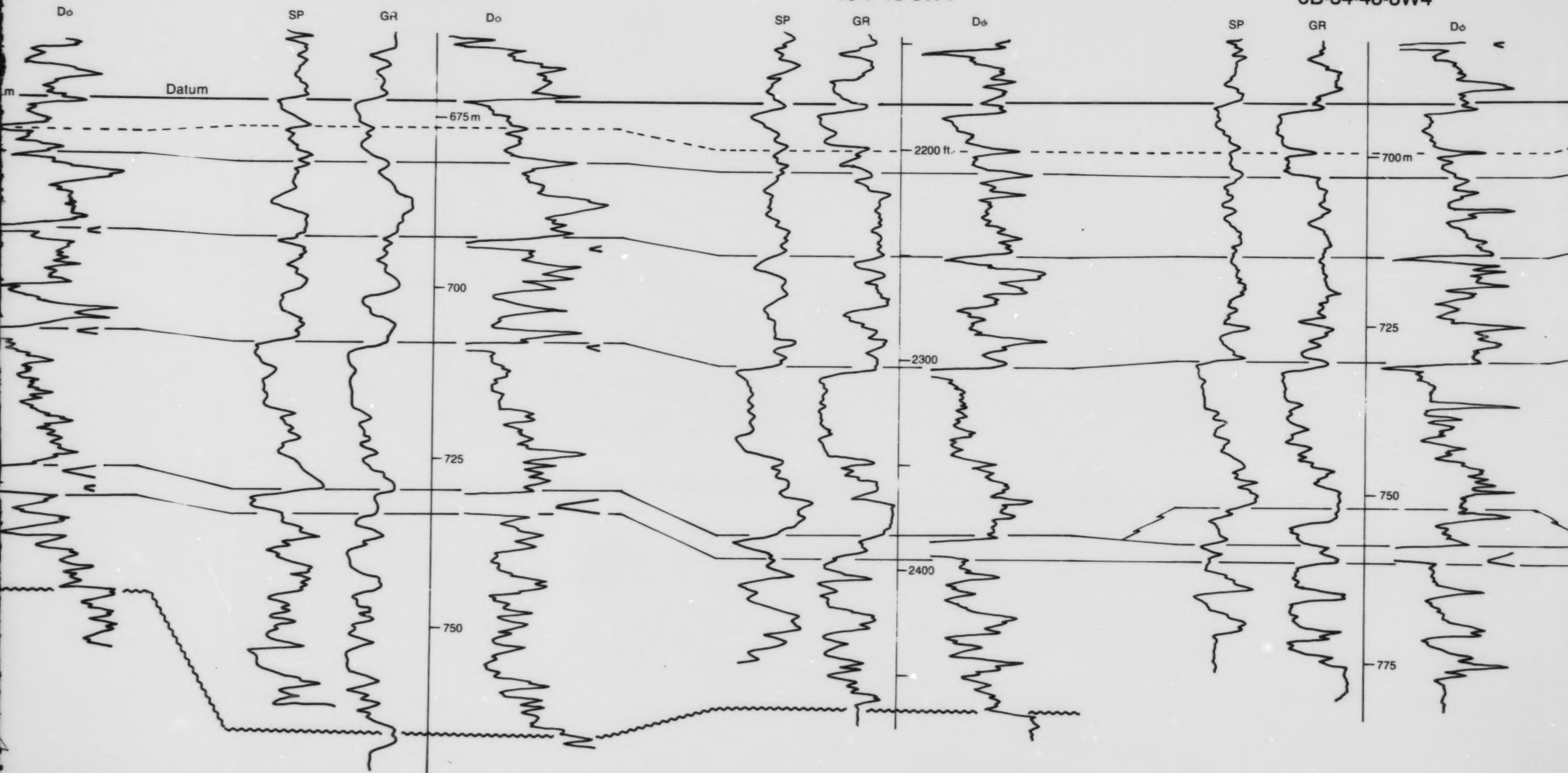
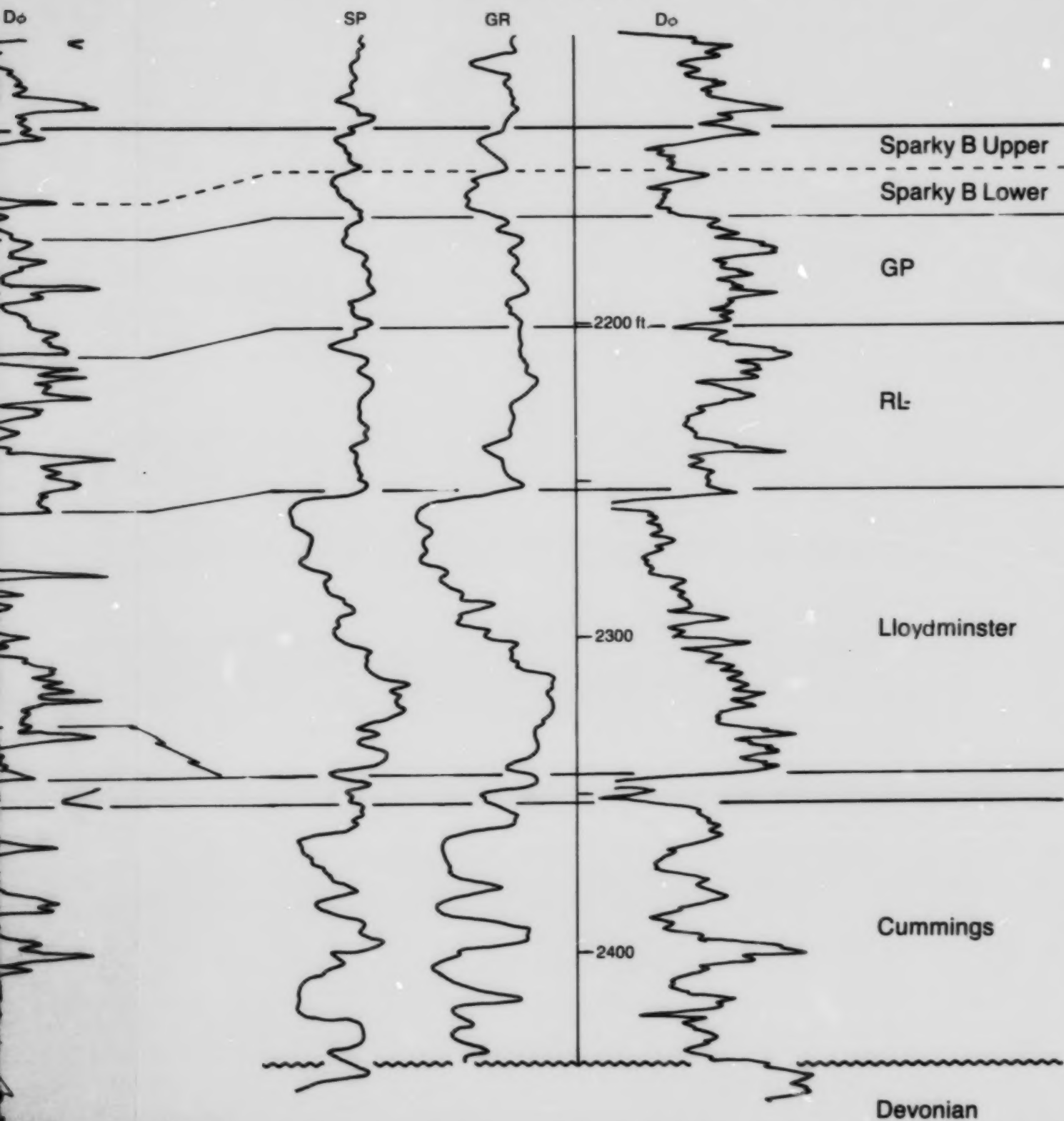


Figure 11. North

10D-21-49-7W4



11. North-South Cross-section; West Central Lloydminster



Figure 12 The Lloydminster Unit (3-1-43-2 w4).
Hummocky cross-stratification.

Lloydminster (figure 27). Therefore, since the Lloydminster unit in the Wildmere area is part of the same sandstone sheet and has a similar coarsening upward well-log profile, it is probable that Lloydminster core from this area displays essentially the same characteristics that would be present in west-central Lloydminster. Core was examined from five wells in townships 47 and 48 in ranges 3, 4 and 5 W4. The complete Lloydminster sequence is seen in wells 10-25-47-3 w4 and 6-23-47-5 w4.

The unit consists of a lower mudstone sequence approximately 3m in thickness, overlain by a fine- to medium-grained coarsening-upward sandstone unit up to 14m thick. The lower mudstone is a brackish, tidally dominated type I lithofacies. The overlying sandstone is a type II lithofacies sequence dominated by planar-lamination and low angle and hummocky cross-stratification with wave ripples (figure 12). This sequence differs significantly from the Lloydminster observed in the south where basal lower shoreface mudstones and sandstones pass upwards into middle and upper shoreface Lloydminster sandstones (O'Connell, 1985). In west-central Lloydminster, the main Lloydminster sandstone is the same as that seen in the south, except that it progrades over shallow brackish semi-enclosed marine bay sediments.

Lower Lloydminster Sandstone

In the northeastern part of the study area a distinct sandstone unit is present at the base of the Lloydminster, overlying the Cummings coal. This is seen in east-west and north-south cross-section (figures 7 and 11) where it appears as a blocky sandstone lying directly on the Cummings coal unit and overlain by the mudstone at the base of the main Lloydminster unit. It forms a lobate sandstone body, up to 8m thick, with an abrupt southern edge where it thins

from 6m to 0m in less than a section (figure 13). The Lower Lloydminster sandstone continues to the east across the Wainwright Ridge, in township 49, to the fourth meridian, as shown in the regional cross-section figure (27). It is not developed in the south Lloydminster area. There is no core recovery from this unit in the study area but it is represented in 1-10-48-4 w4 in the Wildmere field area by a very fine-grained marine sandstone 2.5m in thickness. It is a type I, tidally-bedded sandstone, heavily bioturbated by an assemblage dominated by Chondrites and Teichichnus (figure 14) and lies directly upon the Cummings coal. The upper contact is erosional and has been heavily burrowed and overlain by type I mudstones of the main Lloydminster unit.

The RL and Rex Units

The RL was defined by O'Connell (1985) as the sequence occurring between the Lloydminster and the Rex marine transgressions. In west-central Lloydminster the Rex unit is not correlated or mapped. This is because no continuous Rex sandstone bodies have developed, and, while the unit can be recognized in core, its lithology of mudstone with thinly-interbedded sandstones are similar to the RL and cannot be reliably distinguished from it on well-logs. The RL-Rex extends from the coal unit at the top of the Lloydminster to the coal at the base of the GP and is correlated in the north-south cross-section (figure 11).

Two wells in the study area have cores which include the RL-Rex interval. Figure 15 is a log of one of these sequence, from 7-6-49-9 w4. The RL consists of type I muddy and sandy lithologies throughout. These appear to be shallowing-upwards from subtidal to intertidal and brackish lagoonal sediments. Mud couplets, which form in a subtidal environment, are present in the lower mudstone/sandstone unit and in the main sand unit, but are absent in the upper

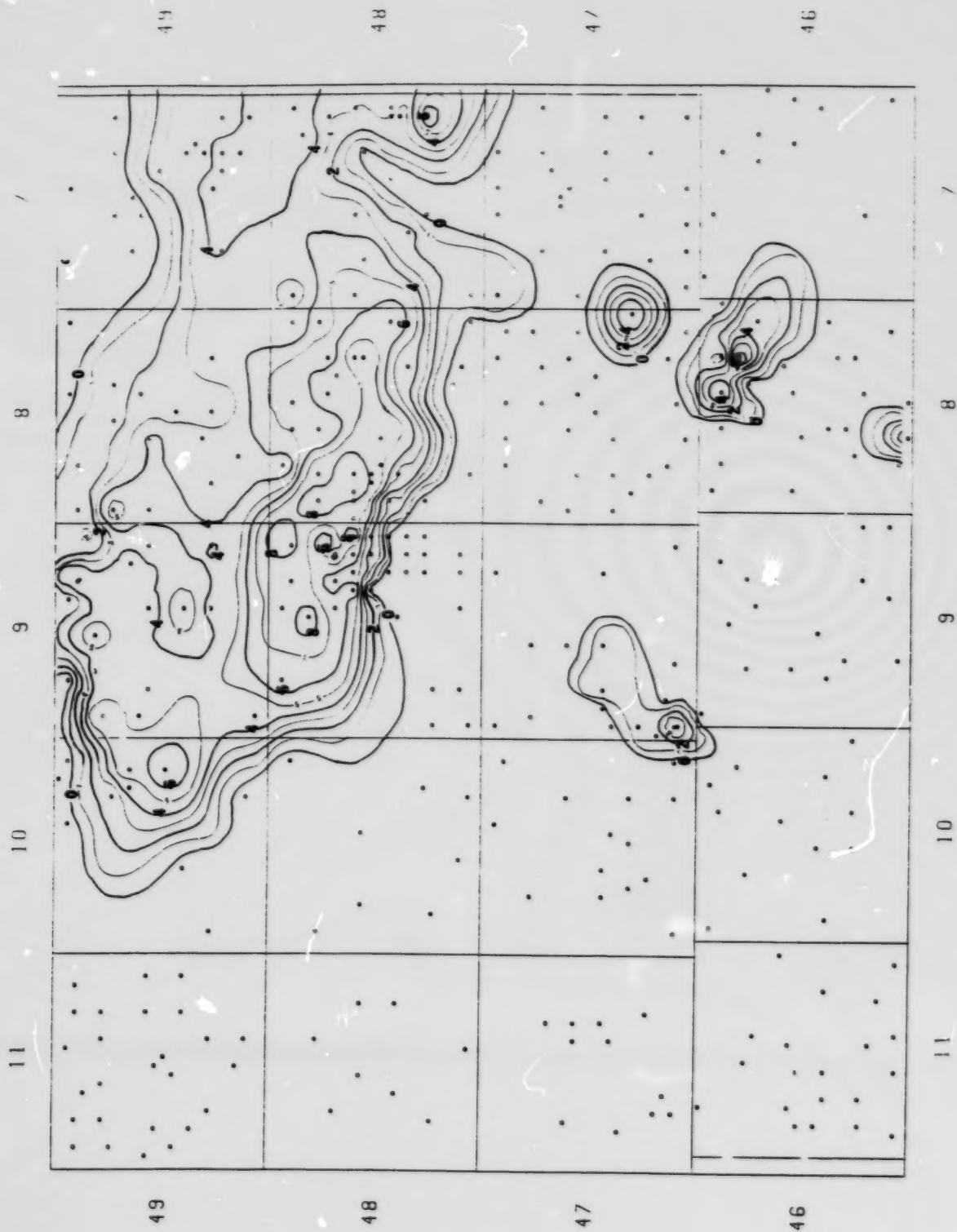


Figure 13 Isopach of the Lower Lloydminster Sandstone in west-central Lloydminster. Contour interval is 1 metre.

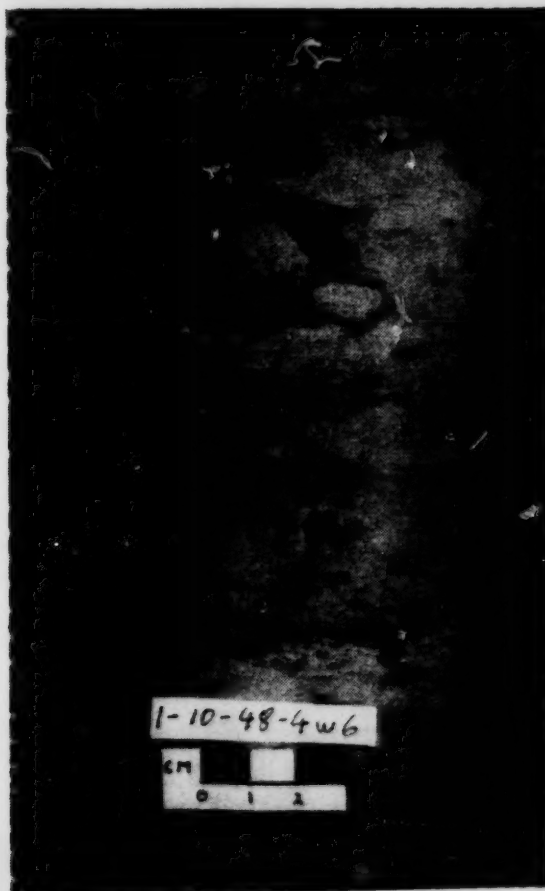
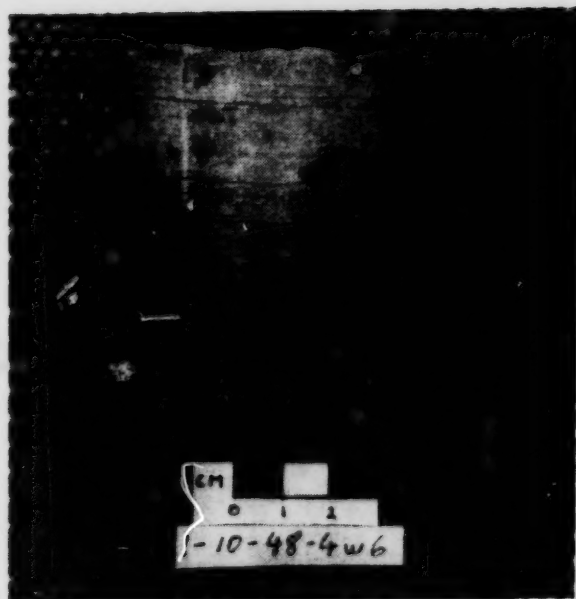


Figure 14 Lower Lloydminster.

- i. Burrowed sandstone with Chondrites, Planolites and Asterosoma.
- ii. Sandstone containing mud-couplets and trace fossils Teichichnus and Chondrites.

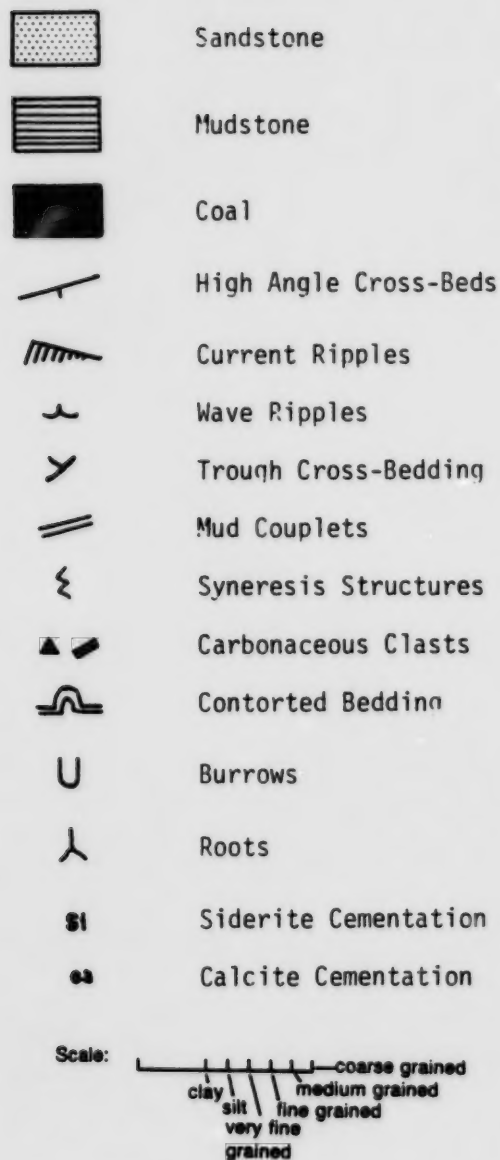


Figure 15a Key to the symbols in Figures 15, 20 and 22.

part of the section. At the top of the unit, black shales containing abundant syneresis structures are present (figure 16). These may indicate deposition in a lagoonal setting where reducing conditions existed. The main sandstone unit within the RL may represent tidal-channel deposition. It is 7m thick with sharp lower and upper contacts and contains both high-angle cross-bedding and planar lamination at the base, indicating high-energy deposition. Climbing ripples and trough cross-beds are present in the mid part of the unit, mud couplets are present throughout (figure 17). However, the unit does not show the fining-upward characteristics typical of channel deposits nor any features consistent with a lessening energy level or emergence at the top of the unit. The Rex consists of a fine-grained sandstone 2m thick. It is highly carbonaceous, with much plant debris. Large vertical Skolithos and Teichichnus burrows occur, and the contact with the overlying coal is rooted.

There is a major change in the RL unit in the western part of the study area. This can be seen in the east-west section figure 7, where it develops into a single coarsening-upward sequence in ranges 10 and 11. In range 12 it forms a blocky sand unit which is shown in more detail in the cross-section in figure 18. The sand unit extends from range 10 to range 12 w4 but is absent in range 13 w4 where the RL returns to its more typical muddy character. There is a separate sandstone body overlying the blocky RL sandstone unit, and in figure 18 this is correlated as a distinct Rex unit. A map of the total sand in the RL at the western edge of the study area is given in figure 19. This shows a north-south trending sandstone unit approximately 3 townships in width with a maximum sand thickness of 15m in the centre of the unit.

The nature of this unit is uncertain. The general coarsening-upward nature of



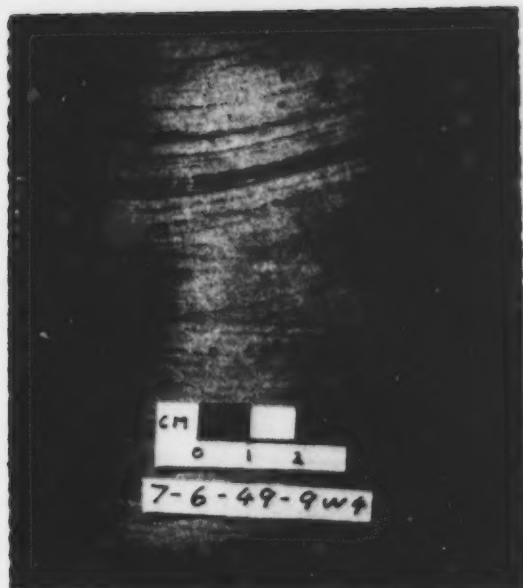
i



ii

Figure 16 The Rex Unit.

- i. Rex Sandstone with Teichichnus burrow.
- ii. Syneresis structures in carbonaceous mudstone at the base of the Rex Unit.



i



ii

Figure 17 The RL unit.
 i. Trough cross-beds with mud couplets.
 ii. Climbing ripples.

Sparky A

Sparky B

GP

Rex

RL

Lloydminster

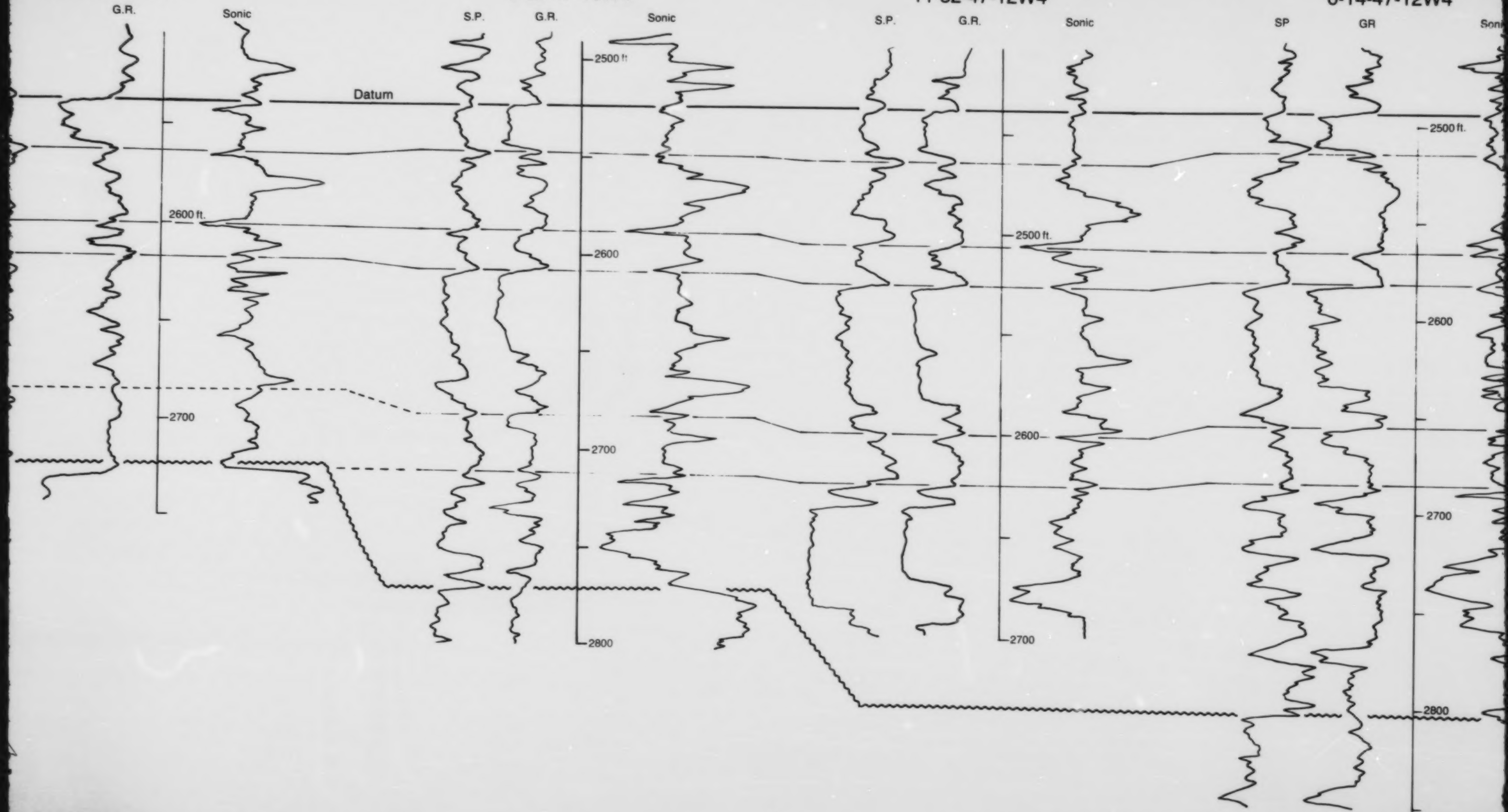
~~~~~  
Devonian

7-33-47-13W4

6-30-47-13W4

11-32-47-12W4

6-14-47-12W4



6-14-47-12W4

4-26-47-11W4

10D-11-48-10W4

SP

GR

Sonic

SP

GR

D<sub>o</sub>

SP

GR

D<sub>o</sub>

Sparky A

Sparky B

GP

Rex

RL

Lloydminster

Cummings

Dina

-2500 ft.

-2600

-2700

-2800

-750m

-775

-800

-825

-850

-750 m

-775

-800

-825

-850

Figure 18. East-West Cross-section through RL sandstone unit

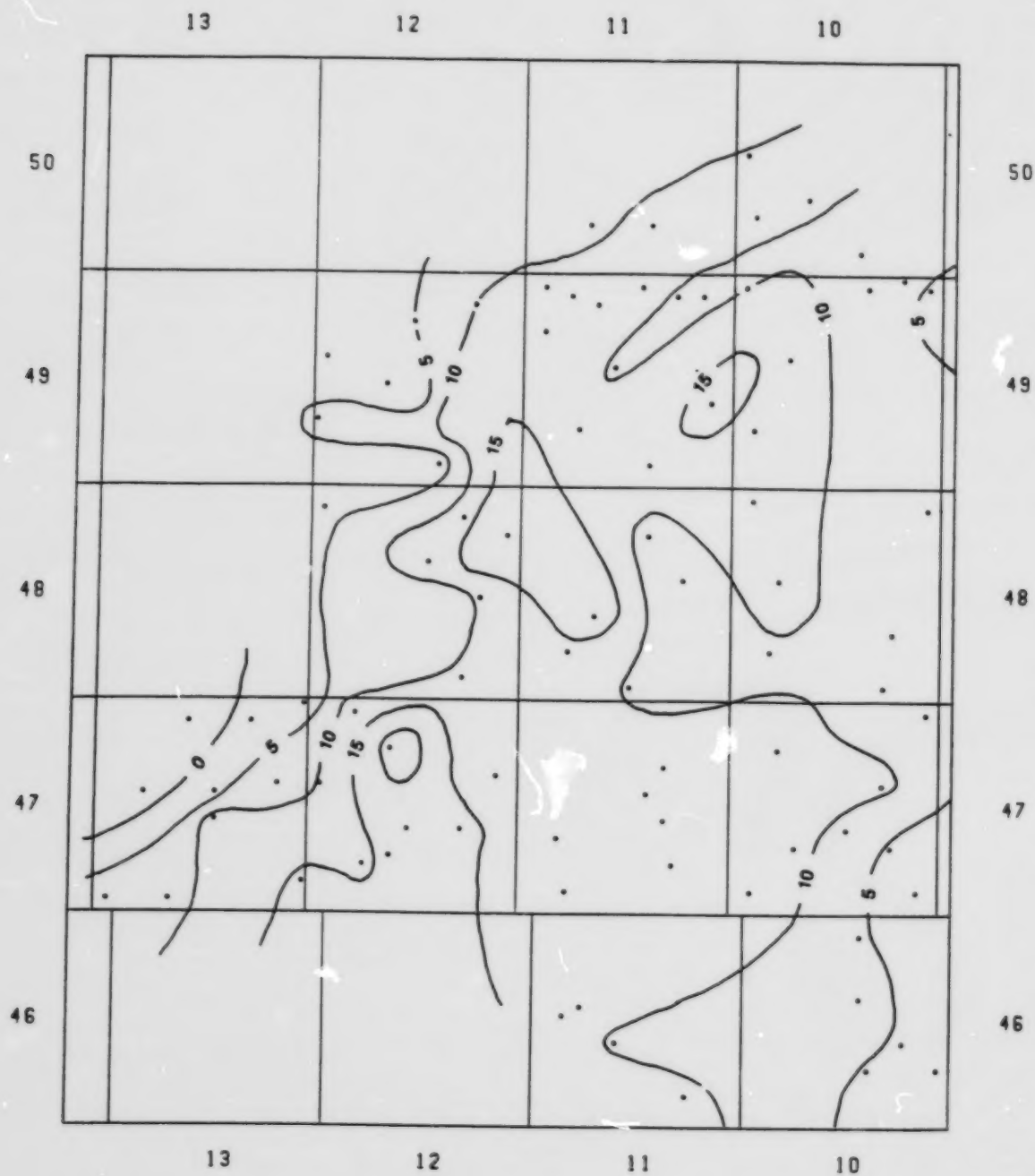


Figure 19 Isopach of the RL sandstone unit. Contour interval is 5 metres.

its well-log profile is similar to the marine Lloydminster unit. The north-south trend of the unit also parallels the north-south shoreline trend of the Lloydminster that is seen further to the east. This may indicate that the RL sand is a marine shoreface unit formed on a north-south trending shoreline following the Lloydminster regression.

#### The GP

The GP unit extends from the top of the Rex coal to the base of the first Sparky coarsening-upward unit. It is between 8m and 12m thick and shows no recognizable thickness variation trends. Throughout most of eastern and southern Lloydminster the GP consists of a regressive coarsening-upward marine mudstone/sandstone unit. In west-central Lloydminster the coarsening-upward sandy unit is not developed and the GP equivalent consists of mudstones with thin non-continuous sandy interbeds.

A log of a typical GP core is shown in figure 20 from 10-23-48-9 w4. The sequence consists of type I sandy and muddy lithologies, deposited in a brackish tidally-dominated environment (figures 21 and 21a). The top of the unit has been eroded but the presence of carbonaceous debris and roots in the uppermost GP sandstone indicate that a coaly unit may have been removed.

Two GP channels are seen in core, one at 10-29-46-9 w4 and the other at 10-17-48-9 w4. Both channels display essentially the same internal and external characteristics. Figure 22 is a log of the GP section in 10-29-46-9 w4. It shows that the GP type I mudstones and sandstones are interrupted by a sand channel 6m thick that fines upward, from coarse sandstone at the base to very fine-grained sandstone towards the top. The sandstone is highly

10-23-48-9w4

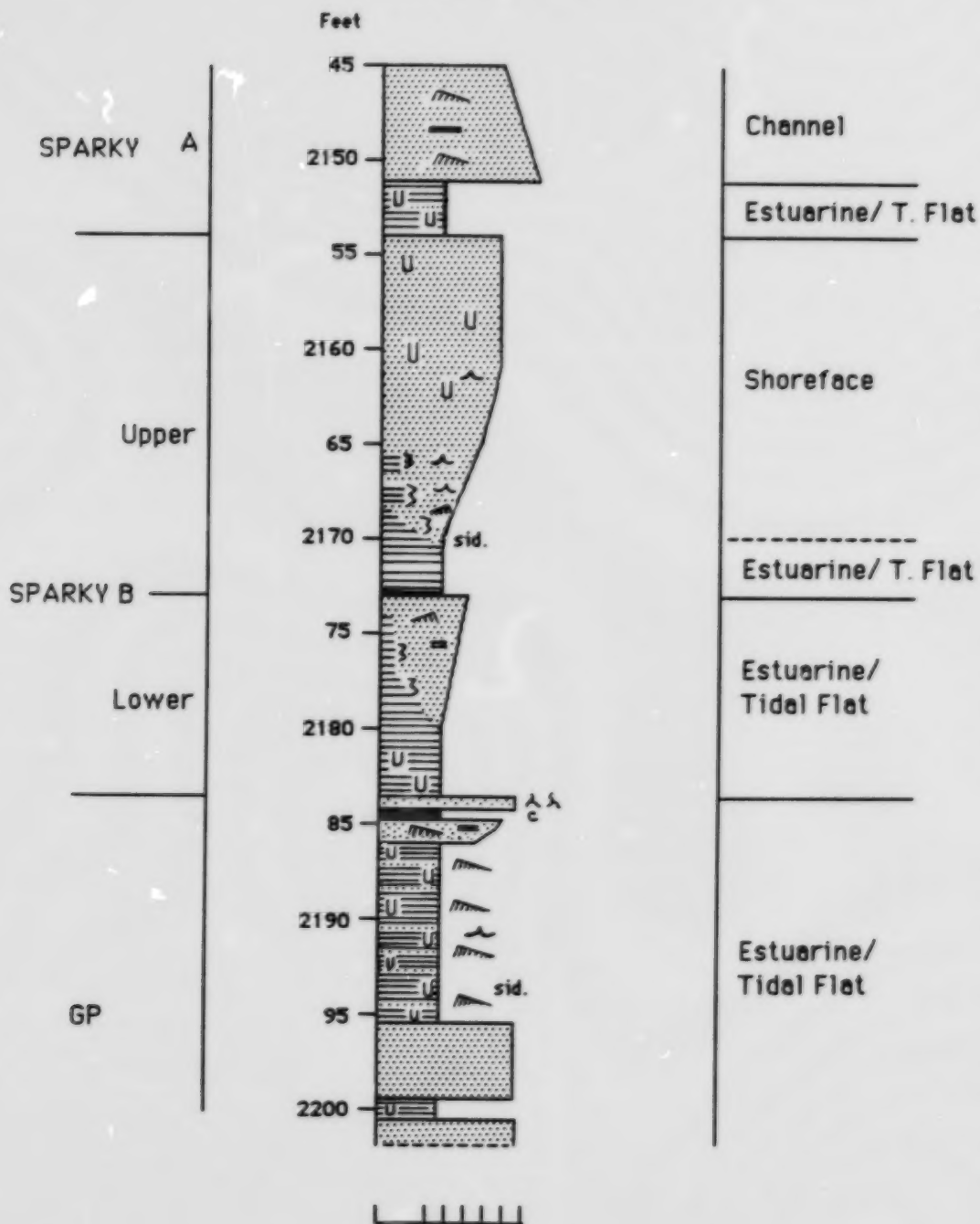
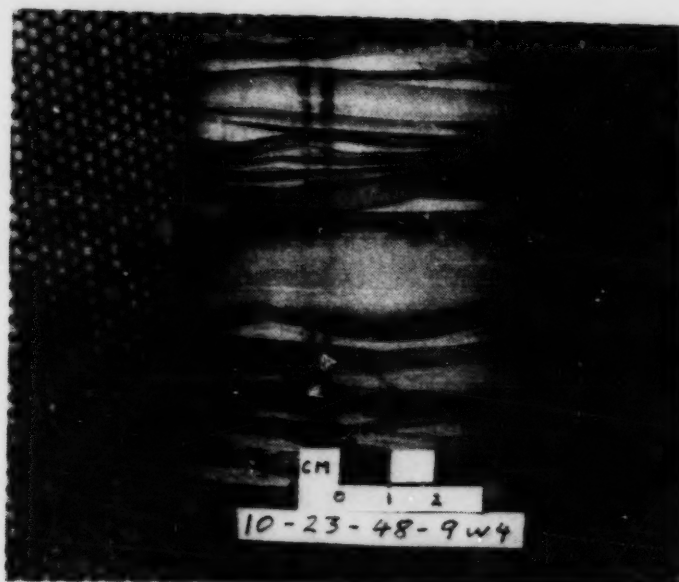
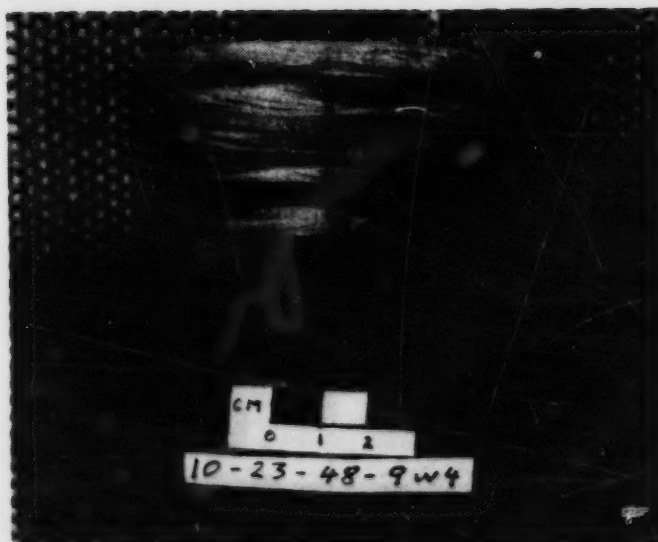


Figure 20 Litholog of the GP and Sparky interval in 10-23-48-9 w4.



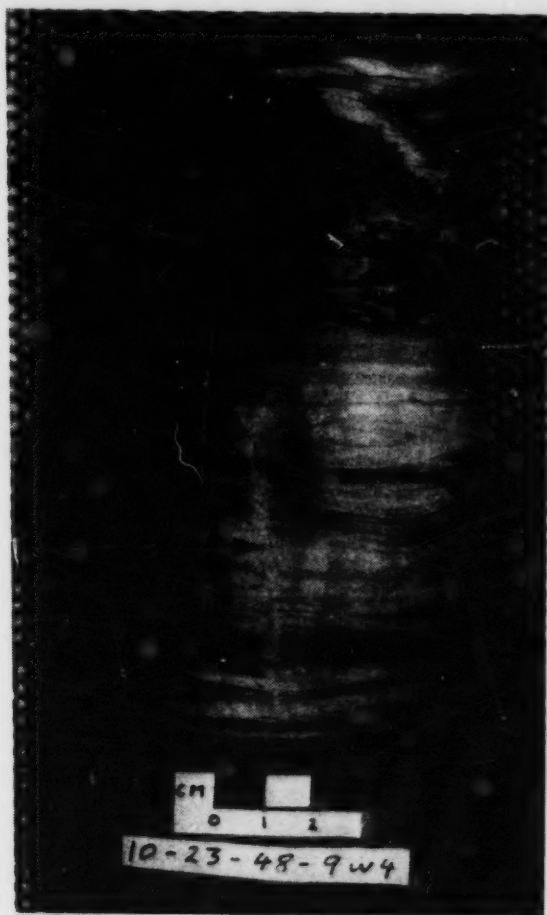
i



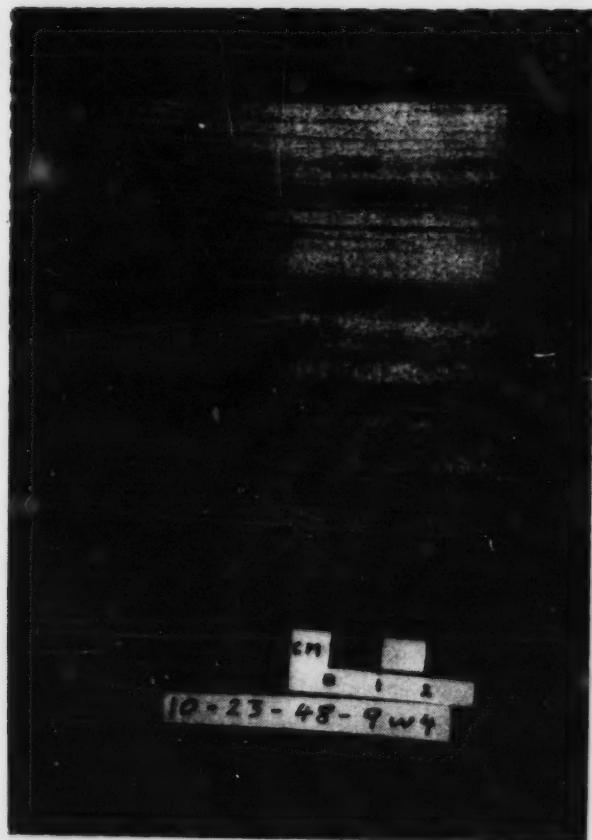
ii

Figure 21 GP Unit.

- i. Interlaminated sandstone-mudstone with wave ripples, current ripples lenticular bedding and isolated sand lenses.
- ii. Interlaminated sandstone-mudstone with isolated current rippled sandstone lenses.



i



ii

Figure 21a GP Unit

- i. Interlaminated mudstone-sandstone with flaser bedding, current ripples, pinstripe bedding and burrows of Skolithos (a) and Teichichnus (b).
- ii. Rhythmic tidal bedding with cross-bedded sandstones.

10-29-46-9W4

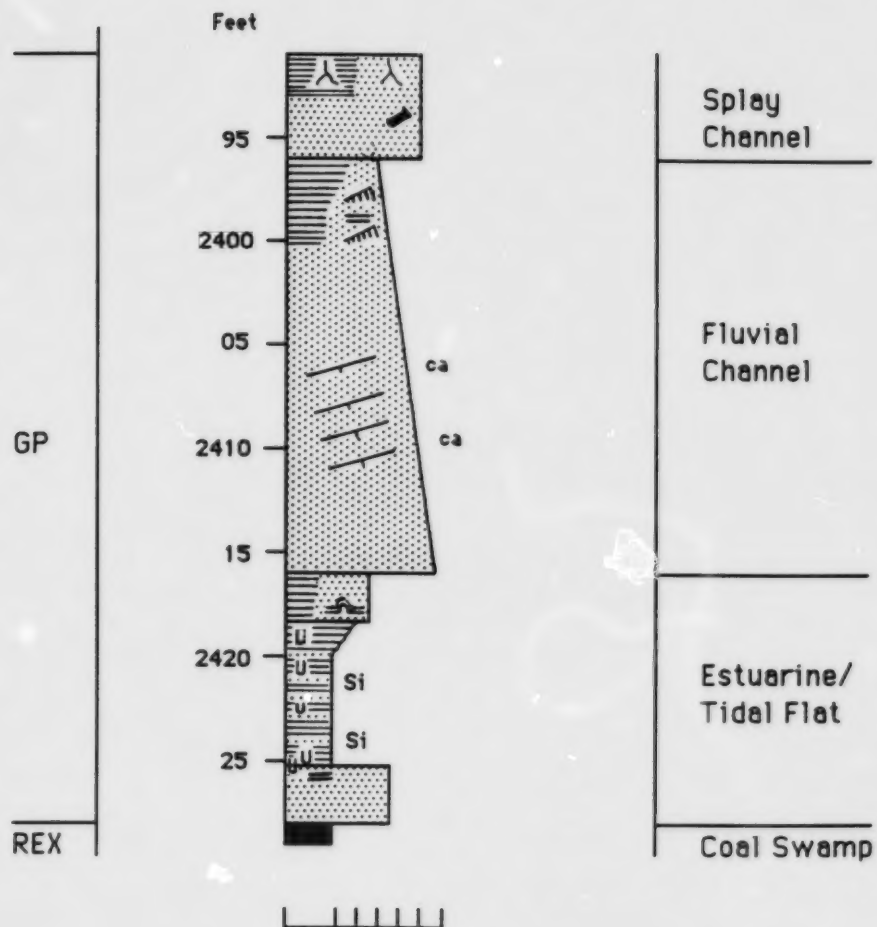


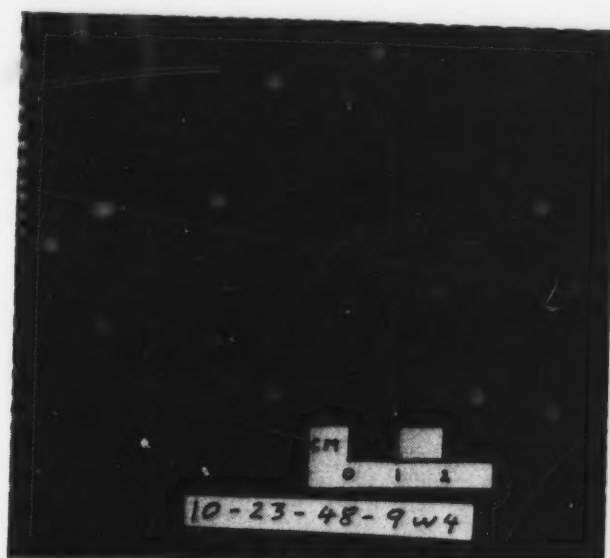
Figure 22 Litholog of the GP interval in 10-29-46-9 w4.

feldspathic and contains a 2m zone highly indurated by calcite. Medium-angle bedforms are present in the lower and middle part of the channel. The upper 1.5m of the channel is a muddy sandstone in which current ripples and mud couplets are present. The channel deposits are not burrowed. Sharply overlying the channel is a 1.8m thick medium-grained sandstone unit containing carbonaceous debris with a rooted zone at the top. The channel and the overlying sand body appear to be type III lithofacies. Tidal bedding features are largely absent throughout the main body of the channel as are brackish indicators. The overlying sandstone is probably a splay deposit associated with the main channel system. The setting for this channel could be upper estuarine to fluvial; the estuarine influence is shown by the sparse mud couplets at the top of the unit.

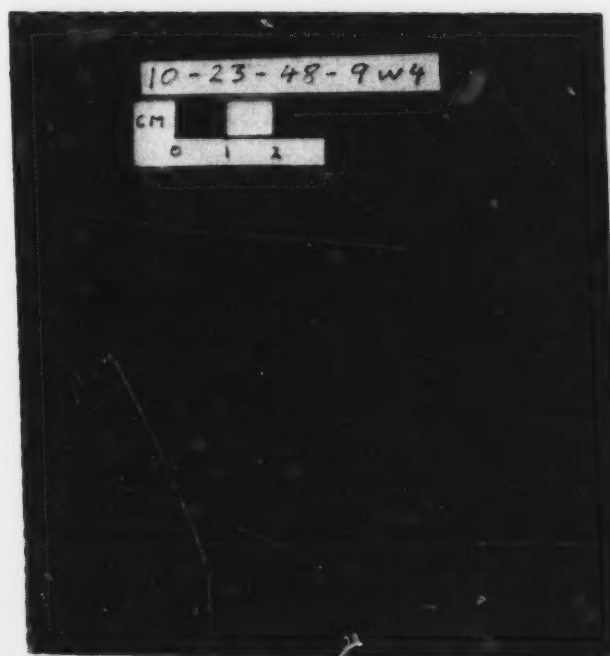
#### The Sparky Unit

This is divided into three units; the Upper and Lower Sparky B and the overlying Sparky A. A log of this section, from 10-23-48-9w4, is shown in figure 20. The Upper and Lower Sparky B are both coarsening-upward mudstone/sandstone units which are continuously developed throughout the area. There are no correlatable sandstone bodies developed within the Sparky A.

The Lower Sparky B is the thinner of the two with an average thickness of between 2m and 4m and usually consists of 1m to 2m of mudstone and interlaminated mudstone/sandstone which passes upwards into a thin sandstone top. The unit consists wholly of type I lithofacies. The sandstone is highly churned with Planolites, Teichichnus and Gyrolithes (Figure 23) present throughout. Few primary structures are preserved but, of these current ripples are common, while wave formed structures were not observed. Palynology from



i



ii

Figure 23 Lower Sparky B.  
 i. Burrowed Lower Sparky B Sandstone with Gyrolithes (a).  
 ii. Highly burrowed sandy mudstone with Planolites (b)  
 and Chondrites (c).

the Lower Sparky B yields a brackish estuarine assemblage. At the top of the unit a thin coaly unit or highly carbonaceous mudstone is usually present. In some cases, where this is absent, remnant structures such as roots or carbonaceous debris are present in the sandstone top.

The Upper Sparky B is the main Sparky sandstone and forms the reservoir unit in the Viking-Kinsella field. The east-west and north-south cross-sections (figures 7 and 11) show that the Upper Sparky B forms a continuous sand sheet across the area with little thickness variation. Maps of the Upper Sparky B total thickness and sand thickness are shown in Figures 24 and 24a. The thickest part of the unit is in the north-central and northwestern part of the area, where it has a maximum thickness of 8m. The thickest sand accumulation is 6m also in the north-central area. The entire unit, as well as the sand content of the unit, thins toward the south; in township 46 it is 4m or less in thickness and the sand is 2m or less. This north-south thinning trend is directly opposite to the Lloydminster trend, where thickness increases from east to west. The Lloydminster has a north-south depositional trend as does the RL sandstone unit. The Upper Sparky B unit alone displays an east-west trend.

The Upper Sparky B unit consists of type I mudstones passing upward transitionally into a type II wave-dominated sandstone (Figure 20). As previously mentioned, there is a transitional zone where the wave and current rippled sandstone contains muddy interbeds with syneresis structures. This zone contains a diverse plankton assemblage which can be classified as nearshore or marine in origin (Appendix 2). Tidal-bedding is sometimes present in this zone. Core in well 13-23-48-9 w4 shows a sandstone containing tidally-

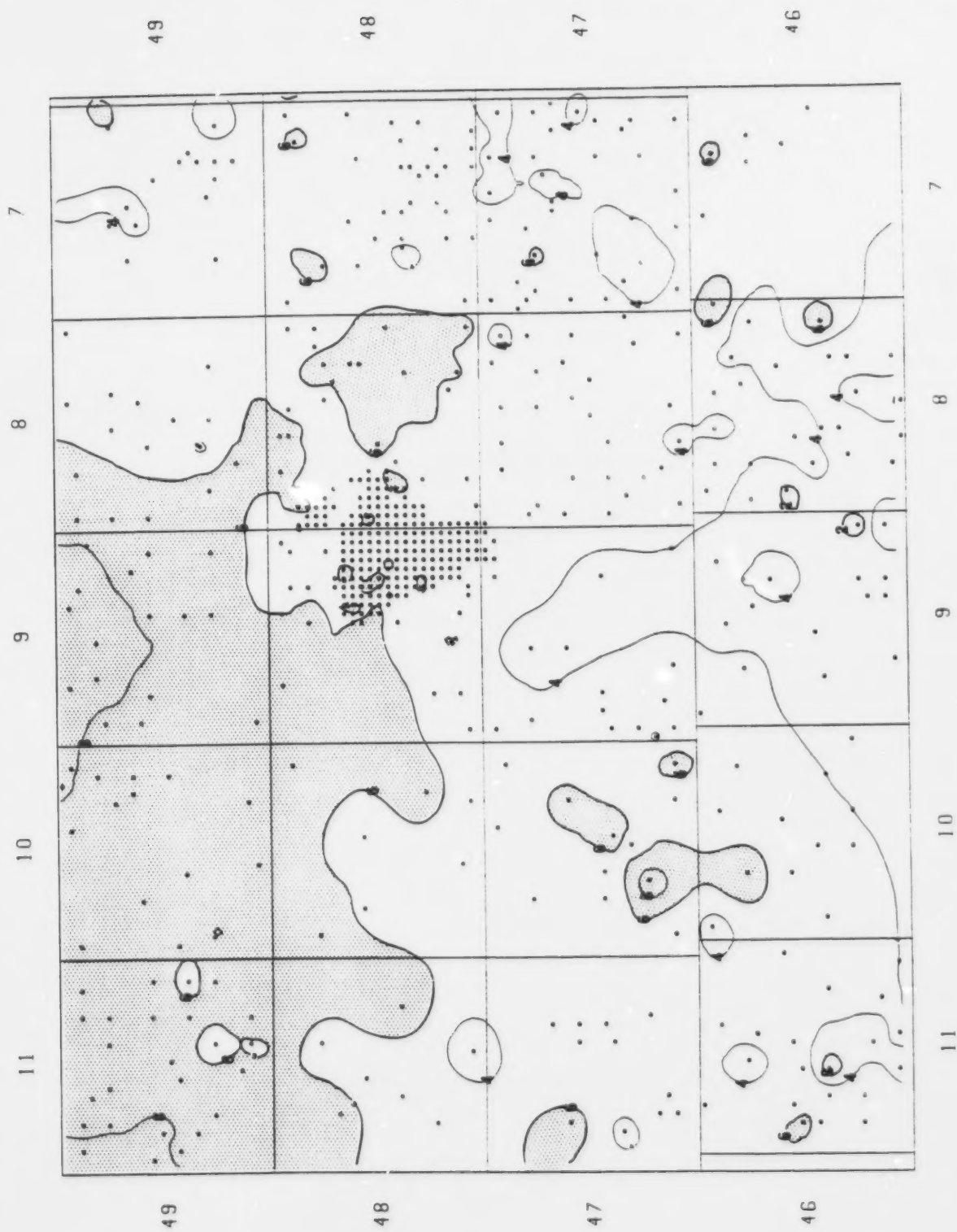


Figure 24 Isopach of the Upper Sparky B unit. Contour interval is 2 metres. The shaded area is greater than 6 metres in thickness.

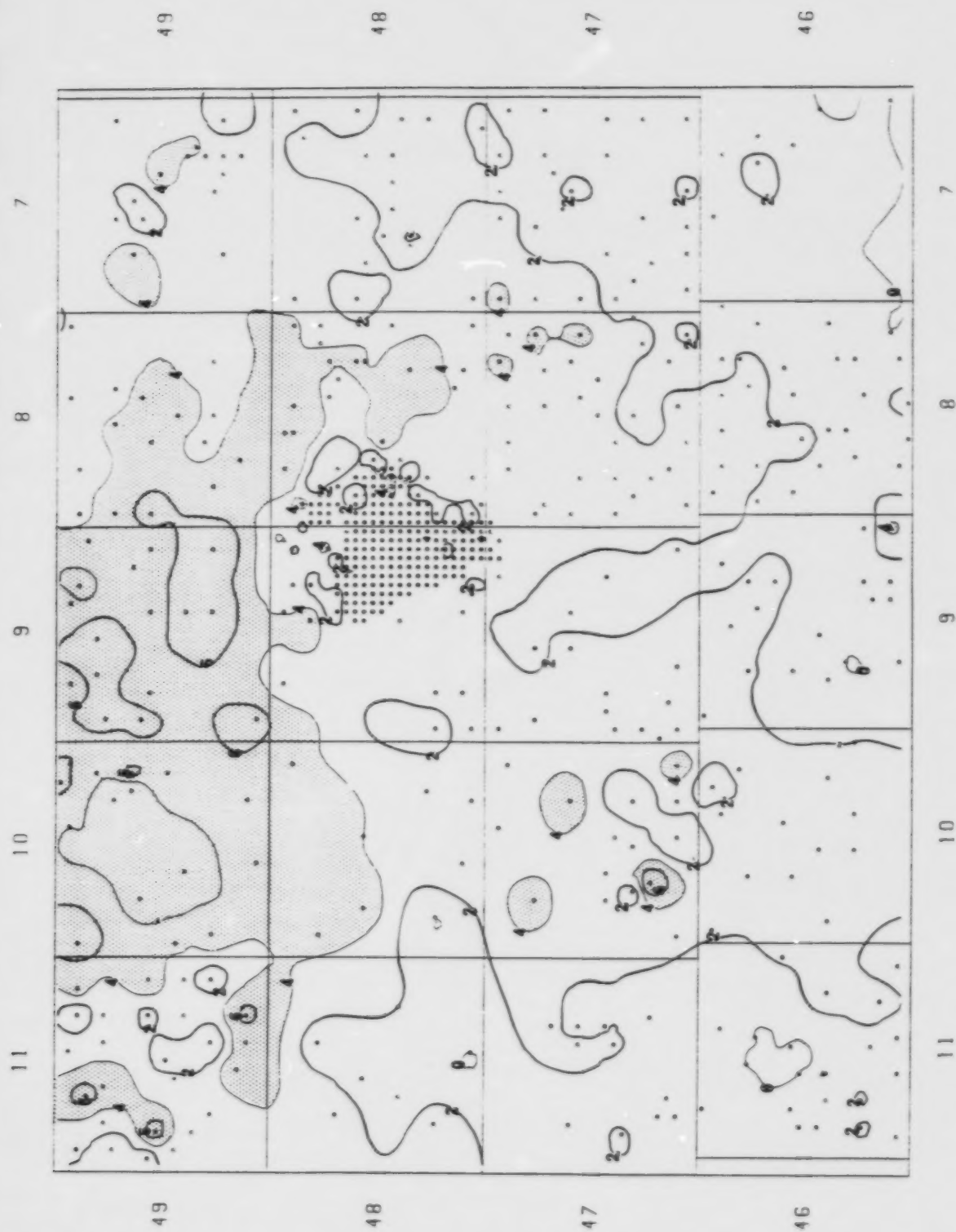


Figure 24a Isopach of the Upper Sparky B Sandstone. Contour interval is 2 metres. The shaded area is greater than 4 metres in thickness.

deposited mud-couplets the top of which has been reworked into wave ripples (Figure 25).

The Sparky A extends from the top of the Sparky B sandstone up to the Sparky coal, which is a regional coal unit in the Lloydminster area. It is the final regressive unit of the mid Mannville, and in south Lloydminster it consists of a sequence shallowing upwards from lagoonal to flood plain deposits. In west-central Lloydminster it is similar in nature. Here, immediately overlying the Sparky B are type I mudstones which pass upwards into type III lithologies, consisting of sharp-based, fining-upward, current-rippled, non-burrowed sandstones and non-burrowed mudstones, siltstones and coals. These sediments were deposited in a fluvial overbank and splay channel environment.

A north-south trending Sparky channel system is present in the Kinsella field area. It originates in the Sparky A unit and bottoms-out at the base of the Lower Sparky B. In most of the wells where it occurs a fining-upward profile from a sandy base to a muddy top is shown. A well from this channel, 10-28-48-8 w4 is shown in an east-west cross-section from the Viking-Kinsella field in Figure 34. This channel consists of a 3m fining-upward sandstone overlain by a 7m shale interval.

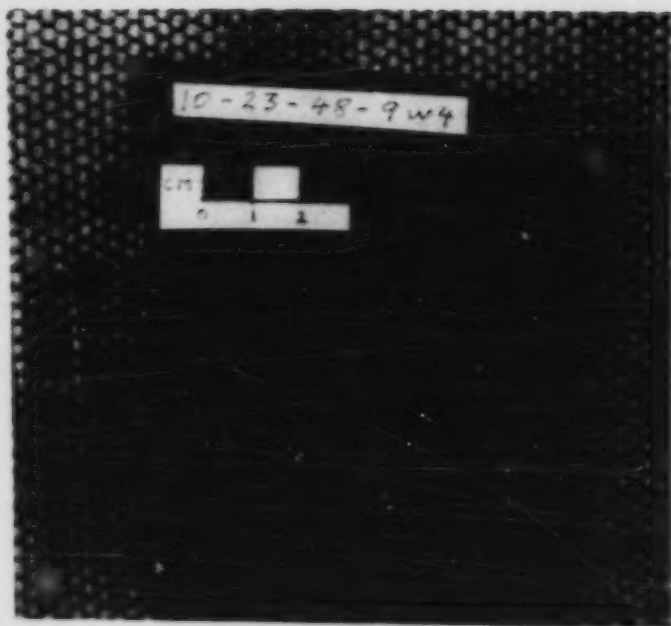
The lower part of the channel is seen in core at 3-17-48-8 w4. The channel is approximately 15m thick and consists of a poorly-sorted, yellowish-grey sandstone with grain sizes ranging from fine to coarse, but without a pronounced gradation in grain size. It is highly feldspathic and is packed with carbonaceous fragments throughout. Medium-angle bedforms are present in the lower part of the channel, with horizontal laminae throughout the main part



i



ii



iii

Figure 25 Sparky B  
 i. Wave rippled Sandstone.  
 ii. Sandstone with tidally formed mud-couplets, the top of the sandstone is reworked into wave ripples.  
 iii. Highly burrowed, oil saturated sandstone.

of the channel. The channel overlies type I mudstones and sandstones, but the contact is obscured. Tidal bedding features such as mud-sand couplets, and rhythmic parallel bedding with intervening rippled sandstones, are outlined by highly carbonaceous laminae and are present throughout the channel. No burrows can be seen in the interval. This is a type III fluvial to upper estuarine sand channel that was deposited in a tidally-influenced setting.

### Regional Cross-Sections

The relationship between the mid Mannville sequences on the eastern and western sides of the Wainwright Ridge is demonstrated by four cross-sections, shown in figure 26. Two of these, figure 27 and figure 28, are east-west sections extending along townships 48 and 47 respectively. The third section (Figure 29) extends southeastwards from township 47, range 8 w4 to township 44, range 1 w4; and the fourth section extends northeastwards from township 45, range 6 w4 to township 50, range 2 w4 (Figure 30).

The relief of the Wainwright Ridge increases from north to south. Figure 27, which is the most northerly east-west section, extends through a particularly low area of the Ridge, and the Cummings is the only mid Mannville unit which thins over this feature. The Lloydminster and Lower Lloydminster units extend throughout the area with little thickness variation. In Figure 28 however, where the ridge is topographically much higher, the Cummings, the Cummings Coal and the Lower Lloydminster are absent, and the Lloydminster is reduced to a thin sandstone. In figure 29 the Lloydminster is absent completely at the crest of the ridge. There is little difference between the character of the Cummings and the Lloydminster units in the eastern and western parts of the area, the only noticeable variation results from units pinching out against the flanks of the Ridge.

There is a much greater variation in the character of the upper mid Mannville throughout the region. The two major regressive marine units, the GP and the Sparky, form distinct coarsening-upward units in the eastern part of the area. These units undergo considerable lithological change above and west of the

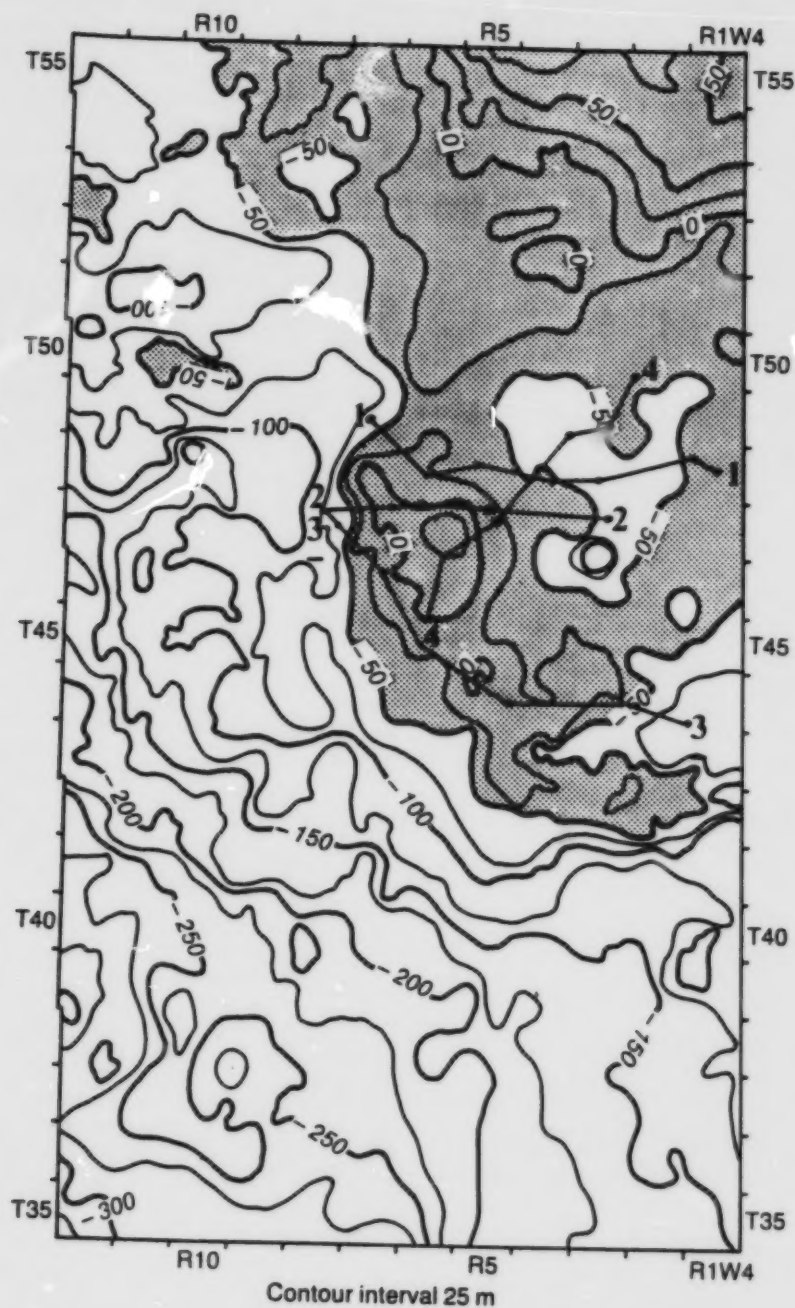


Figure 26 Location of regional cross-sections.  
 1 = Figure 27; 2 = Figure 28; 3 = Figure 29; 4 = Figure 30.  
 Contours are of the sub-Cretaceous unconformity.

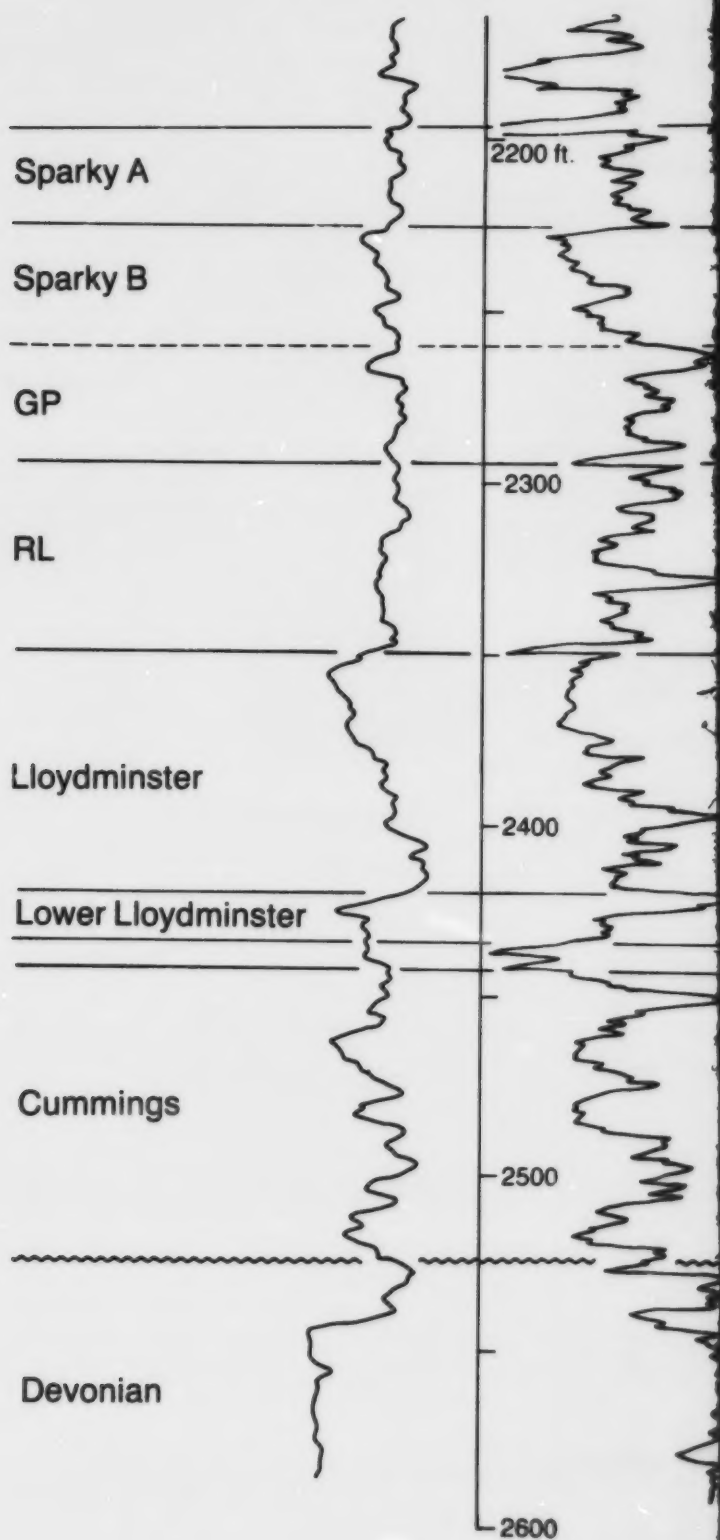
Wainwright Ridge. The influence of the ridge is not as obvious during GP times since it was then covered by sediment (except for a small area in the Wainwright region). However, compaction of the sequence over the feature created topography that caused major GP facies changes. It was noted earlier that the brackish to non-marine character of the GP in west-central Lloydminster is quite different from the correlative marine unit seen in east Lloydminster. The transition can be seen best in figure 30, where the GP unit in range 2 coarsens upward from marine mudstone into a shoreface sandstone. This upper sandstone thins to the west, eventually pinching out in range 4 w4. It is replaced by the brackish/estuarine sequence in west-central Lloydminster. The GP unit seems to disappear entirely over the highest part of the ridge in the Wainwright area (Figure 29).

The Sparky B unit does not seem to have been as severely affected by the ridge and extends across most of the area as a continuous sheet sandstone which generally thins to the west. An exception to this is shown in section 28 in ranges 6 and 7 w4 where it overlies a high part of the ridge. Here the Sparky B coarsening-upward sandstone unit is replaced by a generally fining-upward interbedded mudstone/sandstone interval.

7-8-49-7W4

GR

Dφ



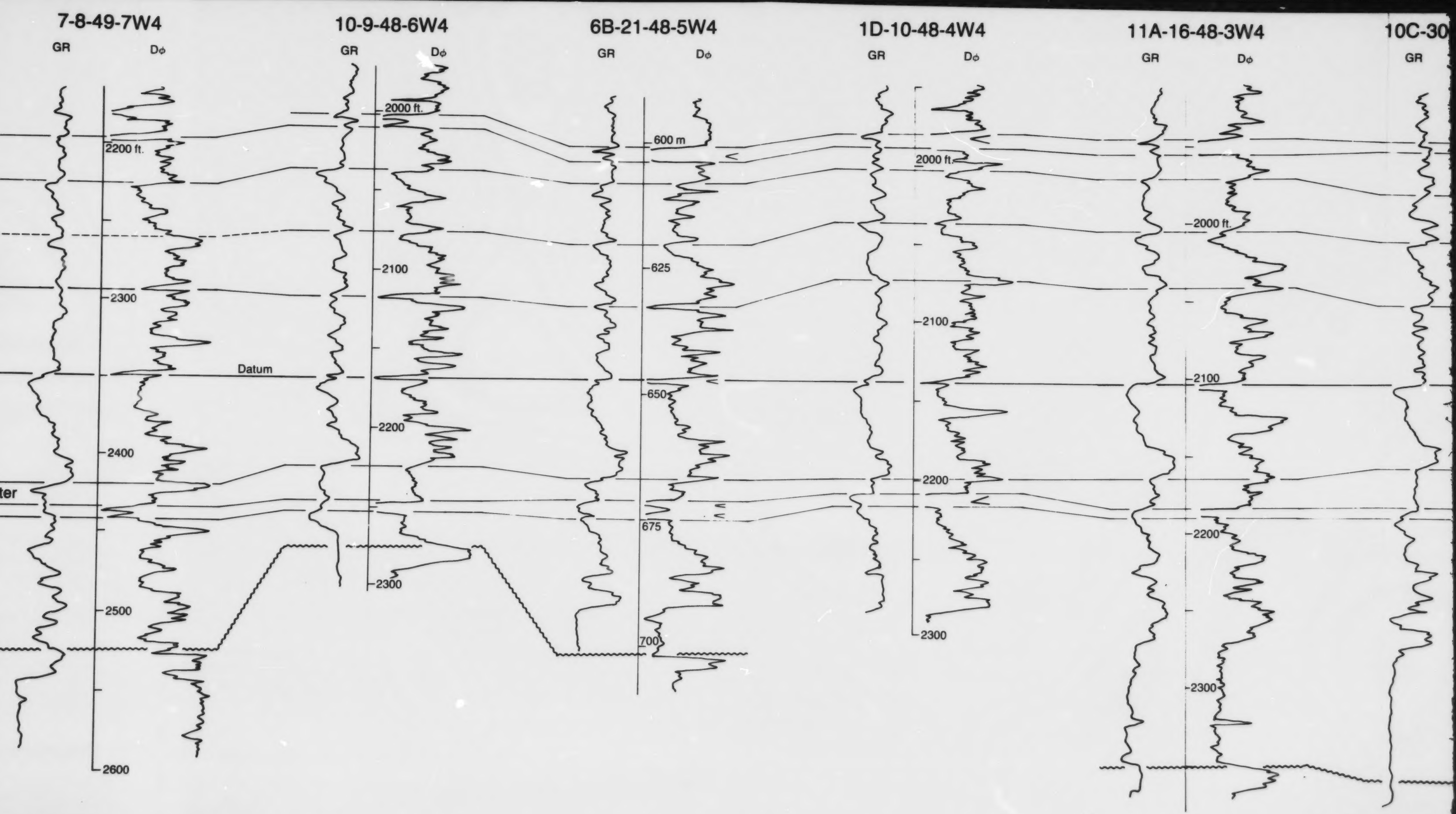


Figure 27. E

10C-30-48-1W4

6-26-48-1W4

GR

D $\phi$ 

GR

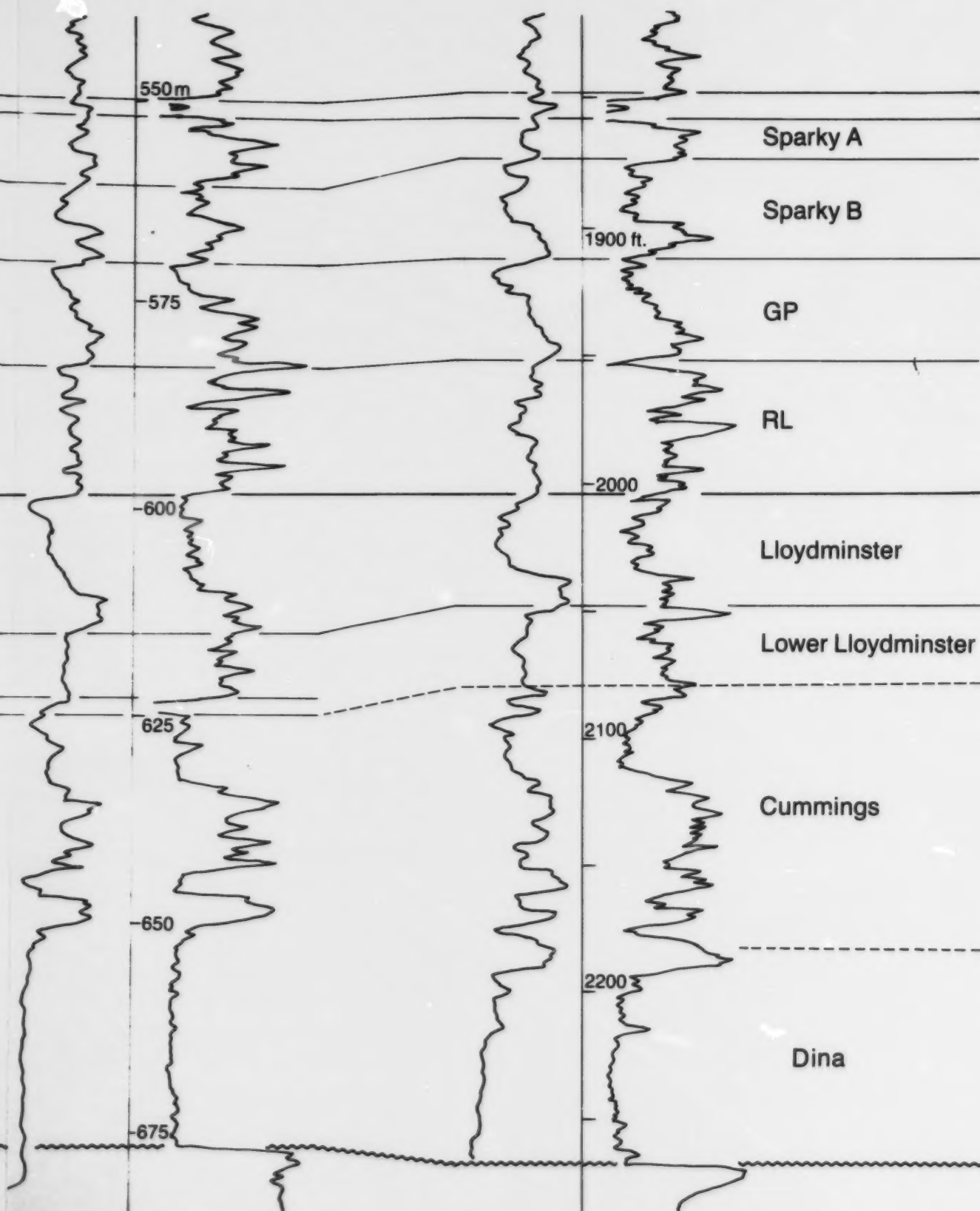
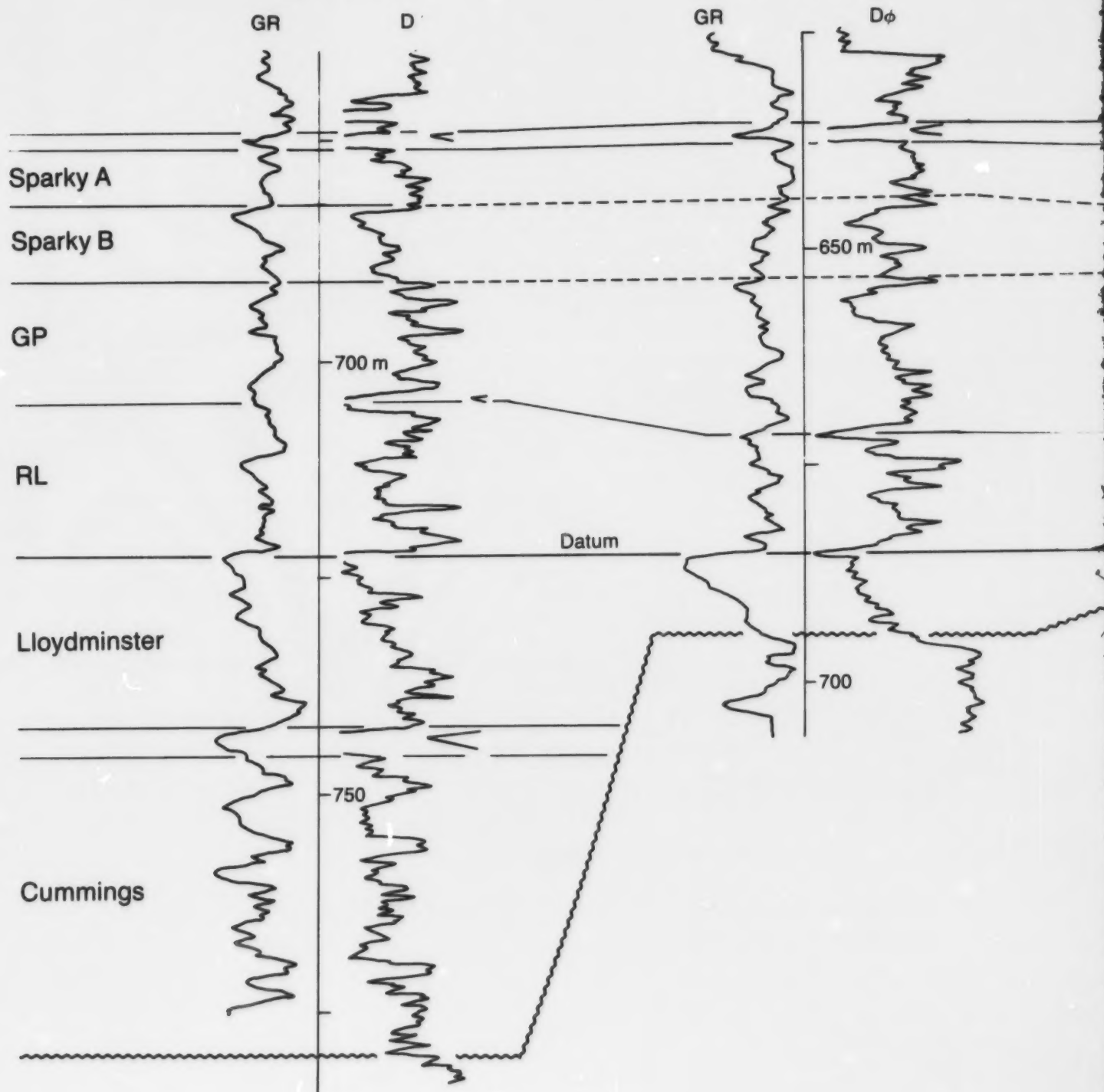
D $\phi$ 

Figure 27. East-West Cross-section; Central Lloydminster

6-20-47-8W4

16-21-47-7W4



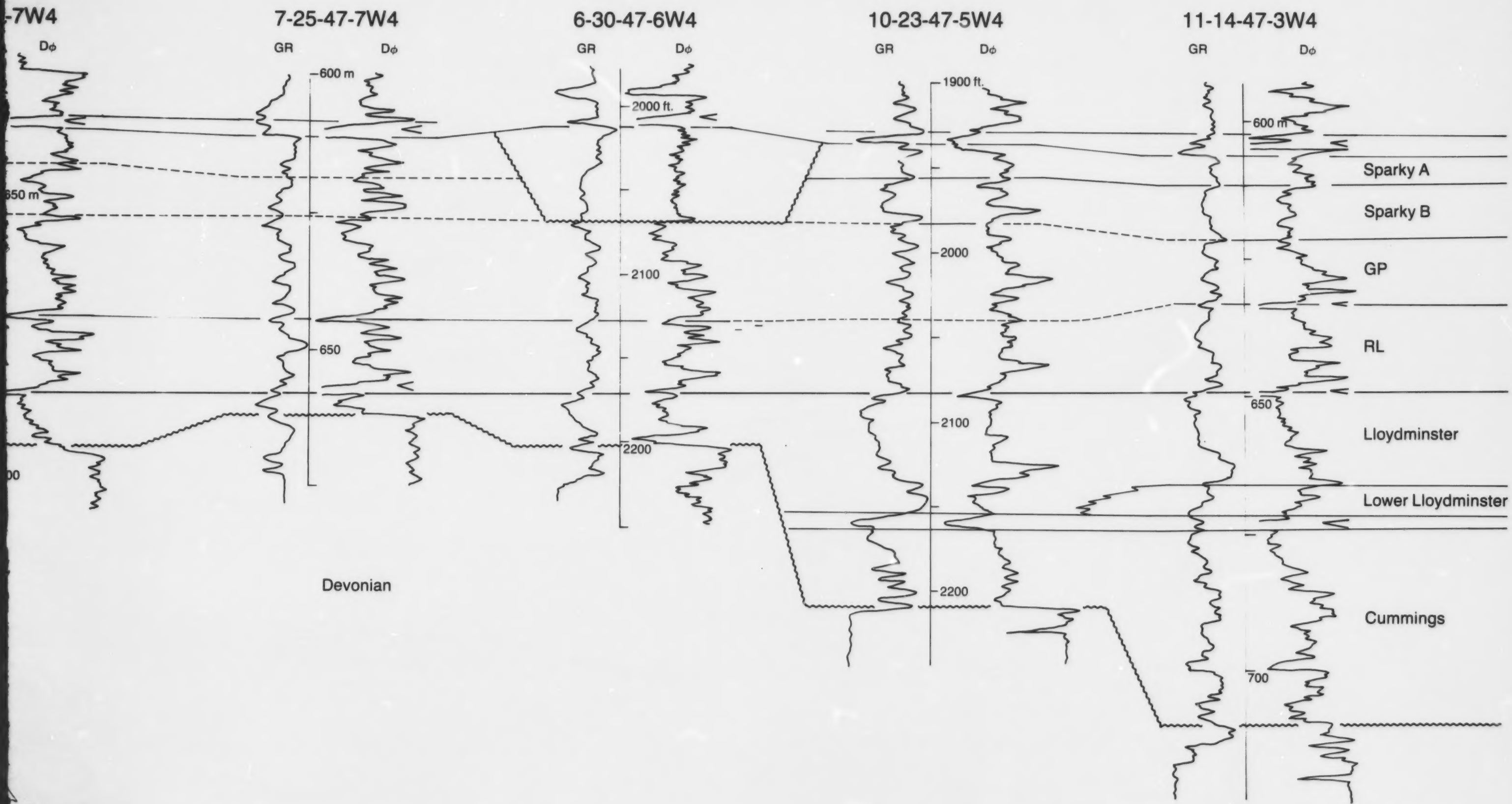


Figure 28. East-West Cross-section; Central Lloydminster

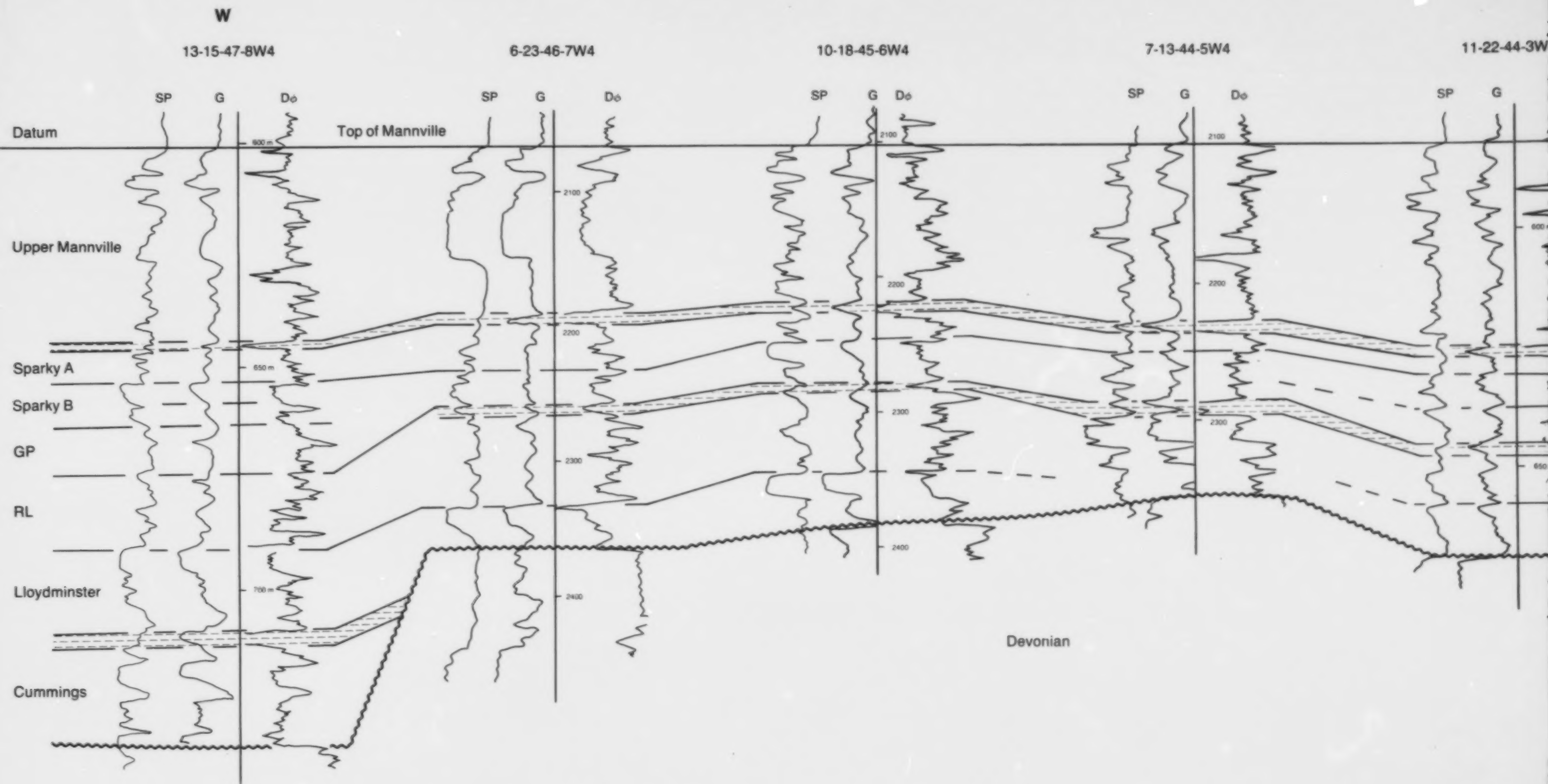
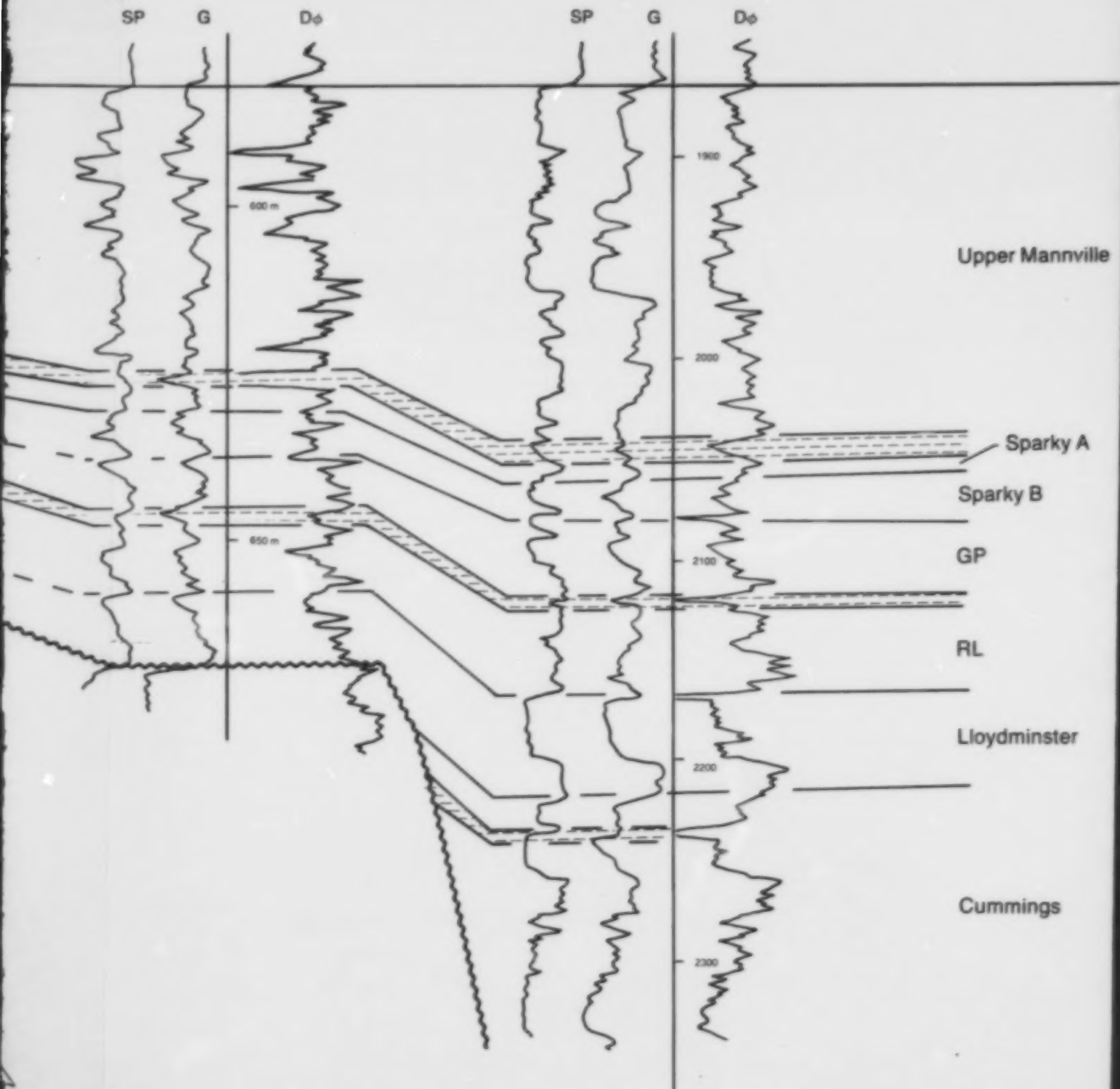


Figure 29. Northwest-South

E

11-22-44-3W4

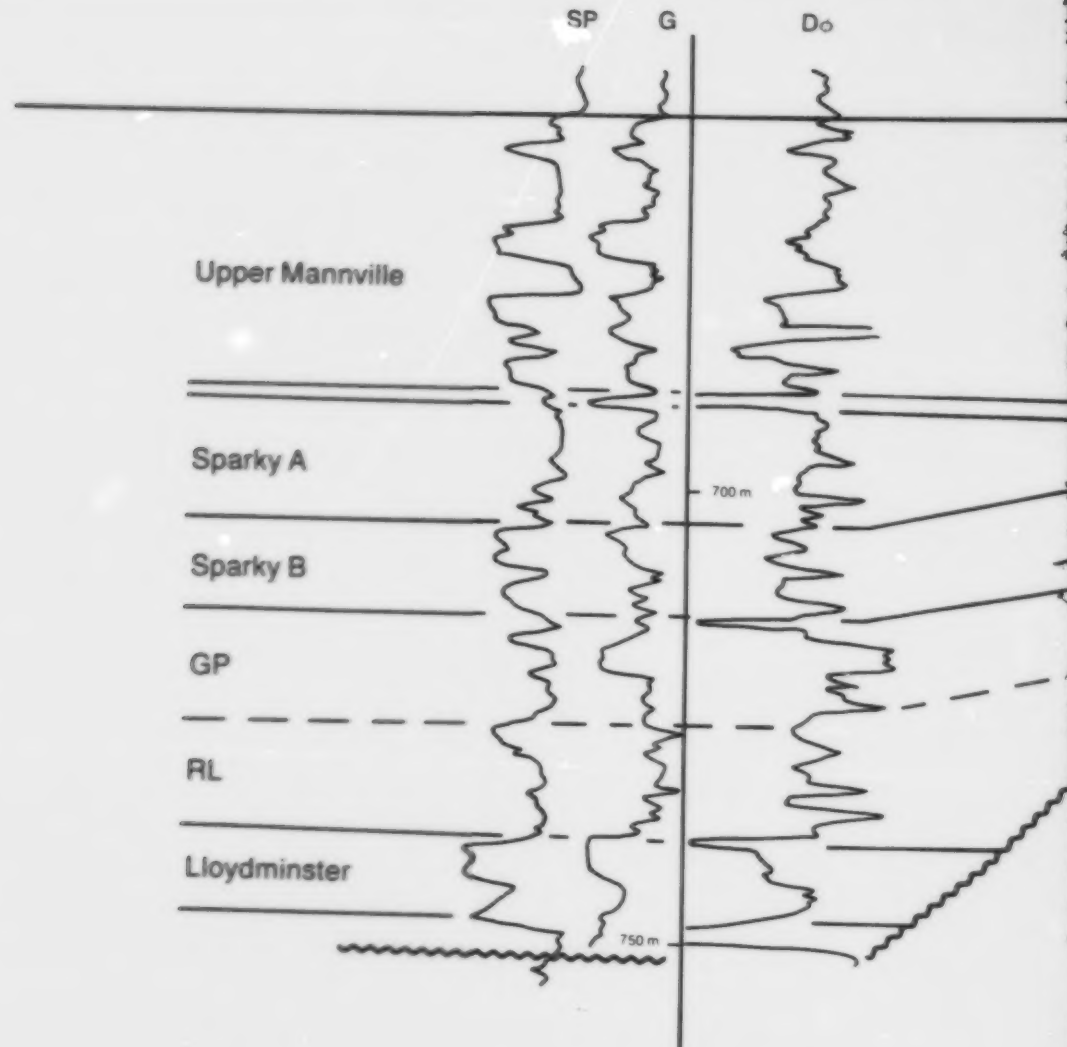
10-8-44-1W4



Northwest-Southeast Cross-section through Wainwright area

SW

10-31-45-6W4



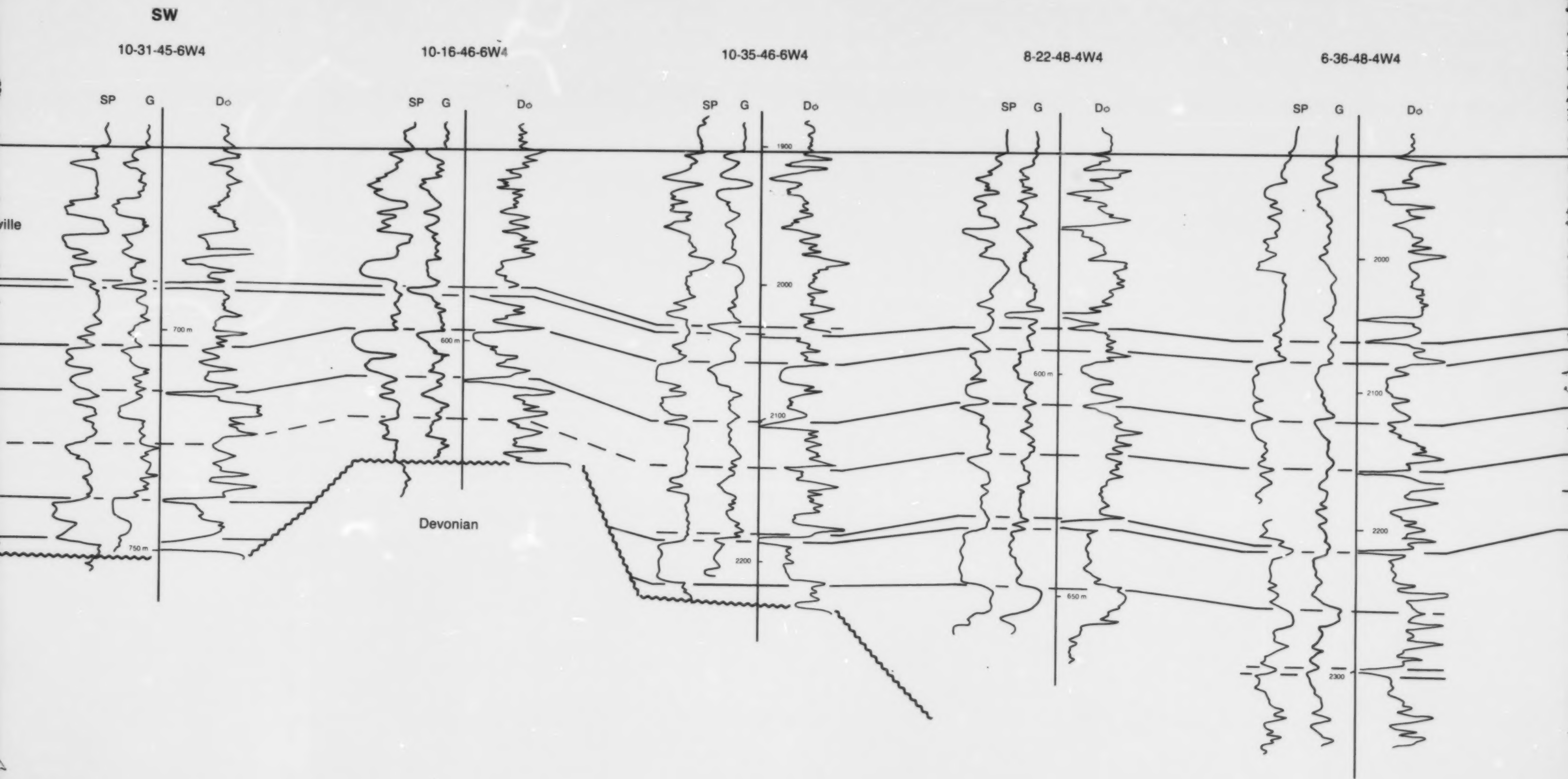


Figure 30. Norther

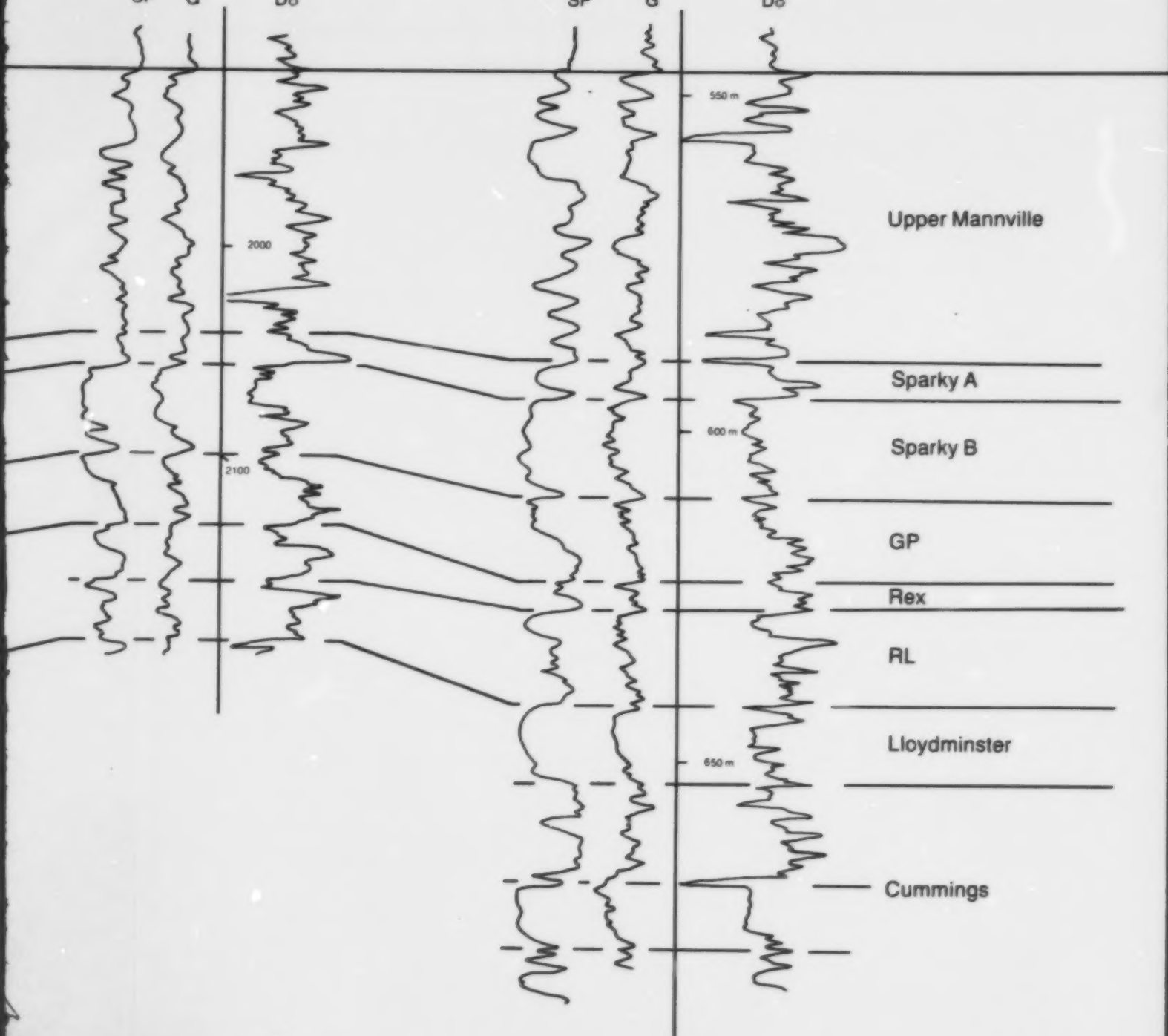
NE

10-10-49-3W4

3-7-50-2W4

SP G D<sub>o</sub>

SP G D<sub>o</sub>



theast-southwest Cross-section; Central Lloydminster

## Discussion

Deposition in west-central Lloydminster was confined by the topography of the sub-Cretaceous unconformity, which created a sub-basin in this area. Within this sub-basin a shallow, semi-enclosed, tidally-dominated, brackish-marine bay developed. The interaction of the sediment types deposited in this setting is highly complex. A range of sub-environments occur from the supratidal to the subtidal zone, incorporating such diverse settings as upper and lower sand and mud flats, tidal, estuarine and fluvial channels, and tidal deltas and washovers. The small amount of core available below the Sparky unit in the study area limits the analysis of these complex depositional settings.

The three basic environmental settings that have been determined from the core analysis are: fluvial/estuarine; brackish/tidal; and high energy marine shoreface. The mid Mannville sequence in west-central Lloydminster may have been deposited in a modified estuarine setting in which an estuarine mouth is partly closed by a barrier-beach complex. In such a case, lagoonal and brackish basinal shales may develop between the marine sand of the estuary mouth and the coarser fluvial sands in the upper reaches of the estuary. A broad sedimentation model for a lagoonal estuary, adapted from Reinson (1977), is shown in figure 31.

In the fluvial depositional realm, meandering river channels deposit poorly-sorted arkosic or lith-arkosic sandstones with an intermediate organic content. Associated with these channels are overbank, splay and other coastal plain deposits. The tidal influences within these channels are indicated by the presence of mud couplets. The presence of thick shale plugs within some



channels may be a result of the flocculation of mud caused by the advance of salt water upstream from the estuary.

The intermediate area of deposition is a mixed/fluvial marine depositional realm. The dominant sediment type is mud. The organic content is high and brackish conditions with associated reducing conditions may prevail. The majority of the RL and GP sediments were deposited in the subtidal zone apparently in muddy or mixed mudstone/sandstone tidal flats. Tidal channel incision is common throughout this zone.

At the seaward end of the model a clean, relatively well-sorted, quartzose sandstone unit was deposited in a high-energy, wave-dominated marine shoreface setting. Deposition was likely in a barrier bar or estuarine delta setting associated with a tidal inlet. It is doubtful whether a progradational delta sequence was ever formed because this would imply that the supply of sediment from the river became dominant. Lower delta plain distributary channels were never established within the sequence. Only twice in the mid Mannville, during the Lloydminster and Sparky B, was a stable sediment supply established. This allowed the deposition of regionally extensive sandstone sheets, thus implying that the sediment supply was regional rather than from a local fluvial source.

Lower shoreface or offshore marine sediments are not encountered within the sequence. Their presence has been noted in south Lloydminster and presumably they are developed to the north outside the shallow west- and east-central Lloydminster embayments.

The Lloydminster, Rex, GP and Sparky units in south Lloydminster are regressive

units with sequences passing upwards from lower shoreface to upper shoreface and coastal plain sediments (O'Connell, 1985). The transgressive/regressive relationships in west central Lloydminster appear to be quite different. Progradation of the sequence shown in figure 31 would result in a classic fining-upward estuarine (Clifton, 1982) or lagoonal (Coleman, 1976) sequence. Shoreface sediments would be overlain by lagoonal/brackish bay sediments which in turn would be overlain by salt marsh, fluvial and coastal plain deposits. This regressive sequence is seen in the GP unit and from the top of the Upper Sparky B to the top of the Sparky A.

A transgressive sequence would consist of fluvial or coastal plain sediments overlain by brackish bay lithologies and shoreface sandstones. This sequence is seen within the Lloydminster and Sparky B units, but these units are not entirely transgressive. A rise in sea level during lower Lloydminster and Sparky times caused flooding of the brackish/estuarine bay and reworking of the brackish and tidally-deposited material in that setting. The shoreface sediments were then deposited during a time of falling sea level when there was a sediment supply available to deposit sheet sandstones across the entire area. The regressive nature of these sandstones is confirmed by the coastal plain sediments that overlie them; the Lloydminster is overlain by a coal unit and the Sparky B by the Sparky A unit.

The depositional setting of each individual unit will now be described.

#### The Lloydminster:

The envisaged depositional environment for the Lloydminster is shown in Figure 31a (i). The Lloydminster marine transgression advanced from the north and

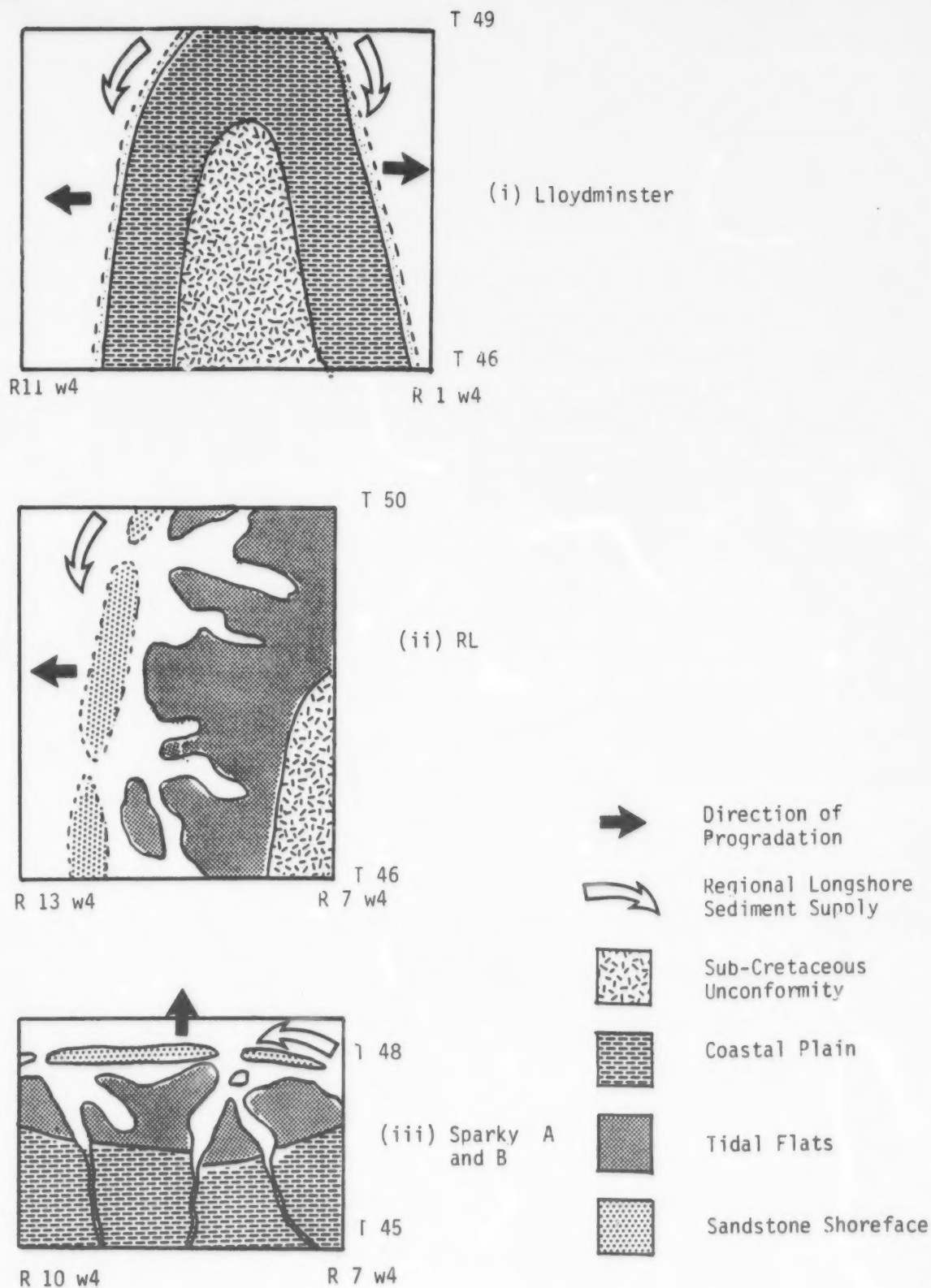


Figure 31a Speculative paleogeography for deposition during the  
i. Lloydminster; ii. RL; and iii. Sparky A and B Units.

surrounded the Wainwright Ridge. As sea level dropped it fell away from the Ridge both to the east and to the west creating north-south shorelines on each side of the Ridge. The Lloydminster is a high-energy wave-dominated strandplain sandstone fed by stable longshore sources from the north (O'Connell, 1985). The ensuing sand sheet on either side of the Ridge was overlain by coastal swamps giving rise to the Lloydminster coal.

#### The Lower Lloydminster

This was deposited in the brackish bay setting that existed prior to the major Lloydminster transgression. It forms a lobate sandstone along the northern end of the southern Wainwright Ridge and may mark the southern edge of a minor transgression prior to Lloydminster deposition.

#### The RL-Rex

Figure 31a (ii) shows a possible setting for the RL interval. The major north to south trending coarsening-upward sand body in the western part of the area is seen as a shoreline sandstone unit developed along essentially the same shoreline trend as the Lloydminster unit. Behind this shoreline a restricted, mud-dominated, tidally-influenced brackish bay was created in which the RL was deposited.

The Rex Unit in south Lloydminster was a regressive shoreline sandstone unit that was poorly developed due to the lack of a stable sand supply at that time. A similar situation appears to have existed in west-central Lloydminster. The Rex transgression probably caused a slight rise in sea level in this area followed by a local reworking of underlying sand units. The unit is capped by a regressive coal unit.

#### The GP Unit

The GP marine transgression did not extend across the Wainwright Ridge and the characteristic GP shoreline sandstone was not developed in west-central Lloydminster. During this time brackish/estuarine conditions prevailed in the study area. A progradational sequence was formed, with brackish sediments moving upwards into coastal plain fluvial and coal deposits.

#### The Sparky Unit

There were two transgressions during this interval. The first one deposited the Lower Sparky B unit in a brackish bay setting. It is similar to the Rex unit in that little sediment was available and a thin local unit was formed within the brackish bay setting and was capped by a regressive carbonaceous mud or coal.

The depositional setting for the Upper Sparky B and Sparky A units is shown in Figure 31a (iii). The setting is seen as a barred estuary giving rise to back-barrier lagoonal and tidal-flat sedimentation. A regional sediment source was available during this time resulting in a continuous Sparky sand sheet across the Lloydminster area. Northward progradation of this sequence gave rise to the Sparky A unit.

## Mid Mannville Resource Analysis

### The Viking-Kinsella Field

The well control in the Viking-Kinsella field area is shown in Figure 32. Two cross sections, Figures 33 and 34 outline the nature of the reservoir unit and the trapping mechanism. The producing zone is the Upper Sparky B sandstone which, as was seen earlier forms a continuous sheet throughout the area. In the Kinsella region this sheet is incised by two channel systems. The north-south trending Sparky channel system, which runs normal to the Sparky B shoreline trend, forms the eastern boundary of the field: the northern boundary is formed by the east- to west-trending Upper Mannville Waseca Channel. North of the Waseca channel a separate Upper Sparky B pool is formed, which is also bounded on its eastern edge by the Sparky channel. The trapping mechanism in the field is created by a combination of channel incision and the regional dip, which is towards the southwest with a gradient of approximately 1:500.

The oil distribution within the field is shown in Figures 35 and 36. The thickness of the underlying water zone in the reservoir is shown in Figure 37. This analysis was carried out by taking well log resistivity values in permeable reservoir zones and calibrating them against commercially available fluid tests which have been done on cores in the area. The results of the testing are expressed as the bulk mass fraction of oil in the rock, which is equivalent to the bulk weight percentage of bitumen. The bitumen saturation was divided into a zone of rich pay where the bulk weight of bitumen is greater than approximately 5%, and lean pay where the bulk weight of bitumen is less than 5%. Gas zones do occur in this field area but they are thin (usually a metre or less) and sporadic, so they were consequently not mapped.

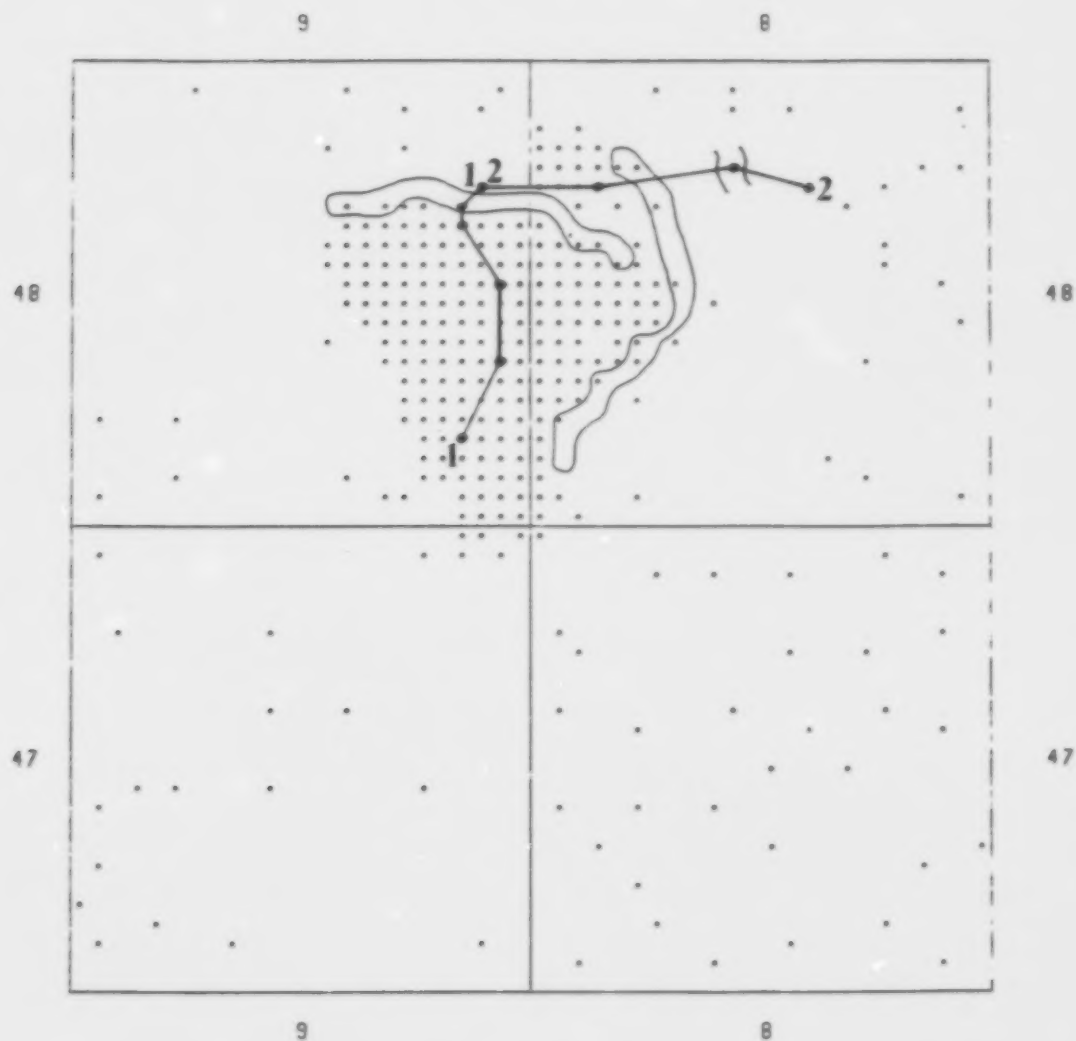
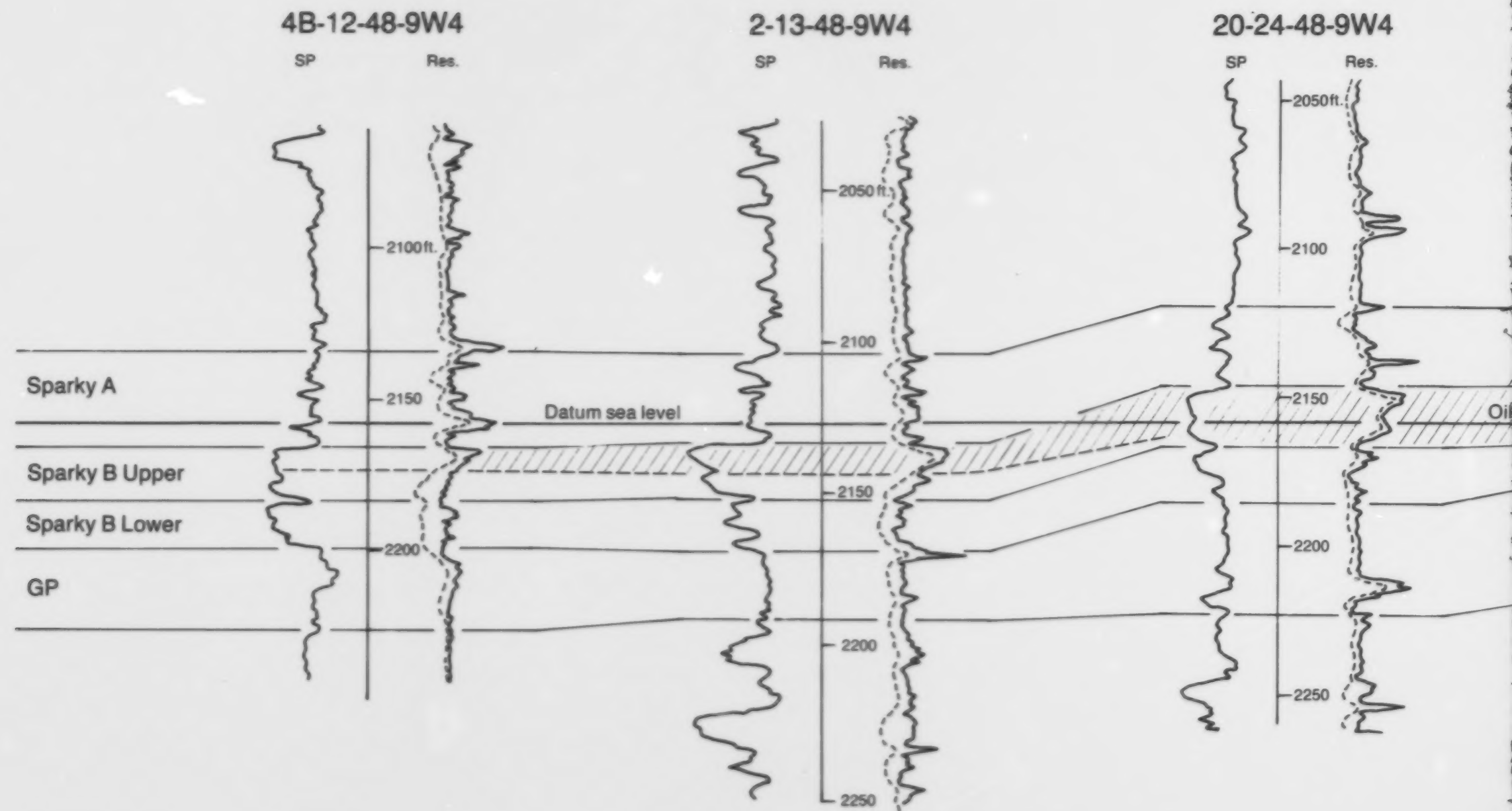


Figure 32 Well control in the Viking Kinsella Field area showing channel trends and the location of the cross sections in Figures 33 (1), and 34 (2).



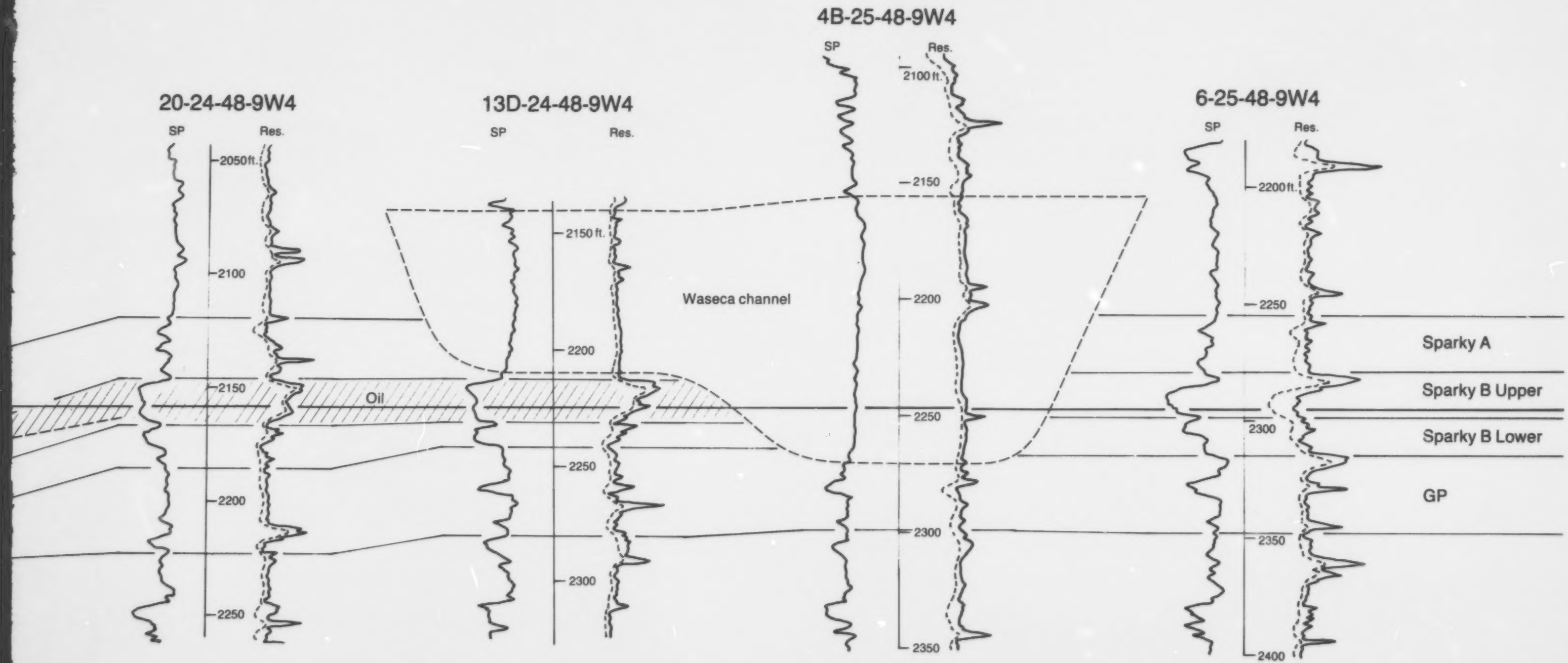


Figure 33. North-South structural Cross-section; Viking-Kinsella field

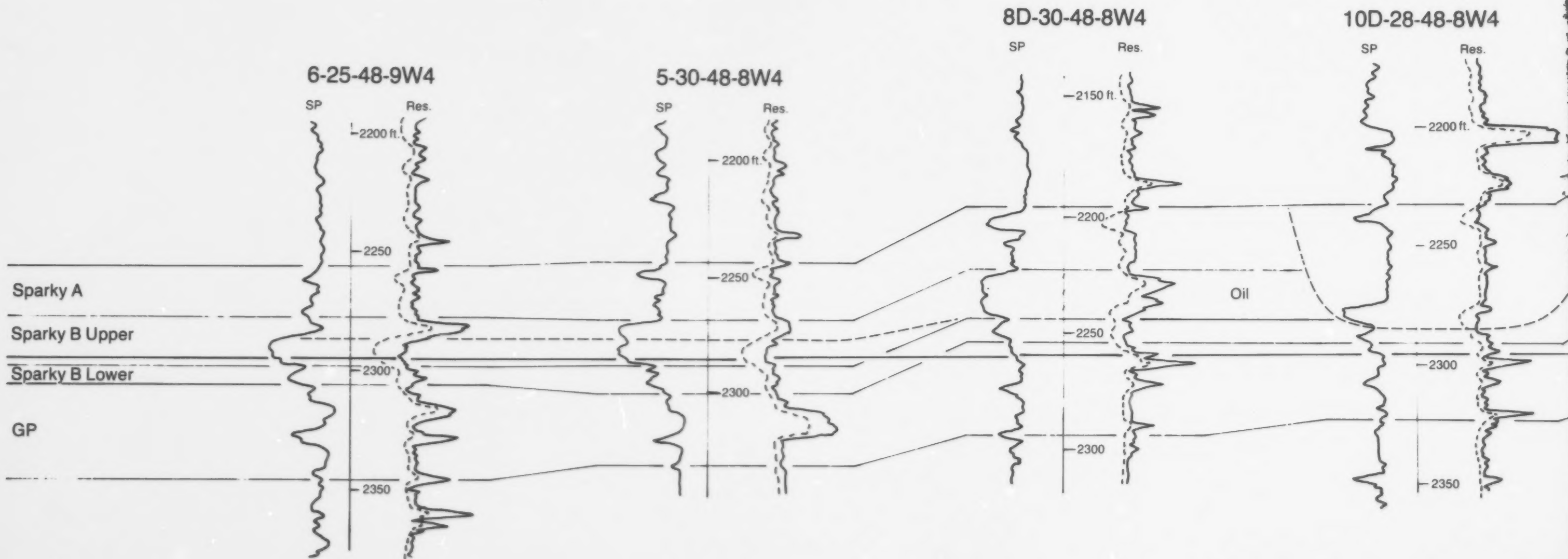


Figure 34. East-west struc

7-27-48-8W4

SP

Res.

10D-28-48-8W4

SP

Res.

- 2200 ft.

2150 ft.

- 2200

- 2250

- 2250

Sparky A

Sparky B Upper

Sparky B Lower

GP

Datum sea level

- 2300

- 2300

- 2350

East-west structural Cross-section; Viking-Kinsella field



Figure 35 Viking-Kinsella field showing bulk weight of bitumen > 5%.  
Contour interval is 1 metre.

8

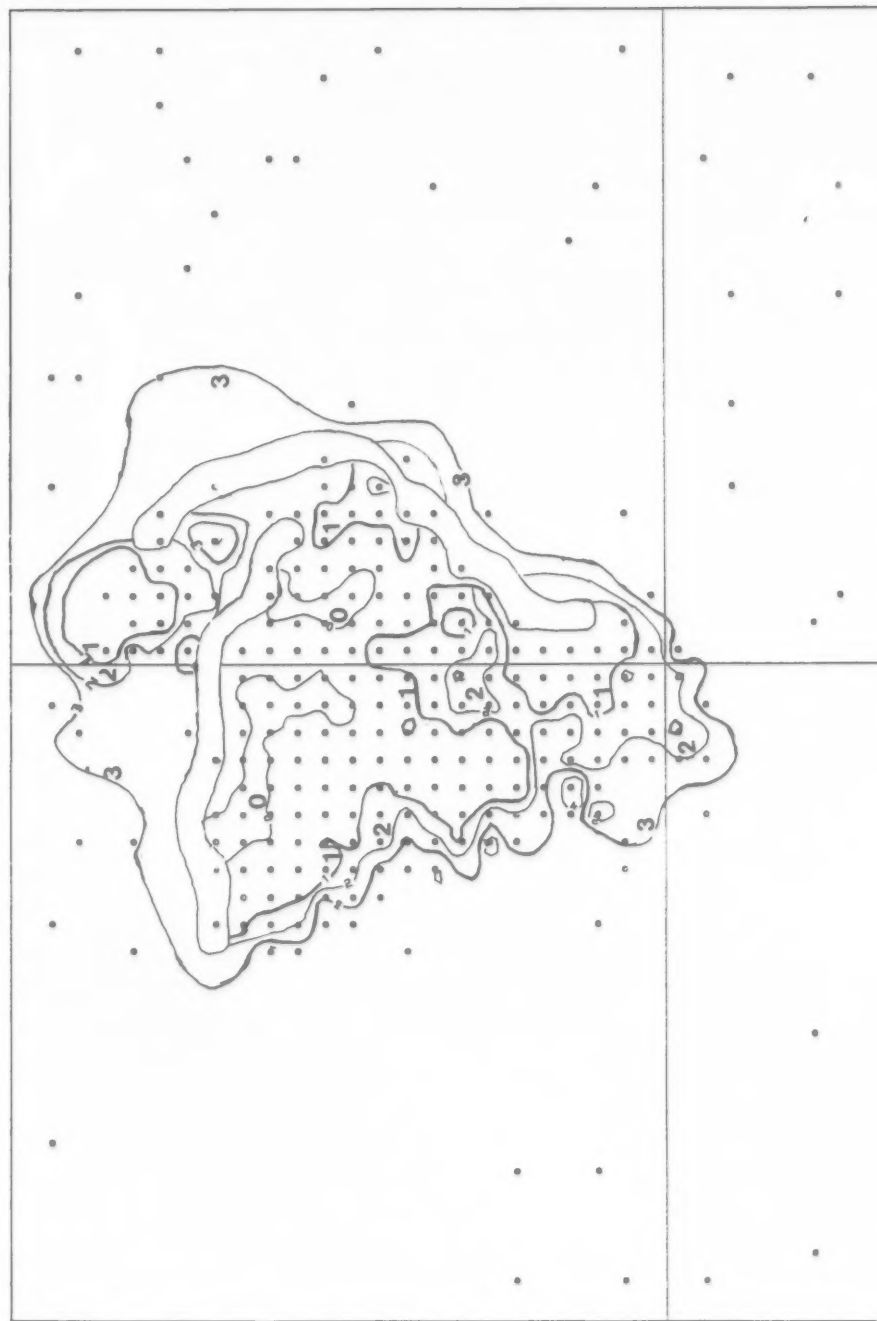
9



Figure 36 Viking-Kinsella field showing bulk weight of bitumen < 5%.  
Contour interval is 1 metre.

9

8



48

48

Figure 37 Viking-Kinsella field showing underlying water zone in the reservoir unit. Contour interval is 1 metre.

The greatest thickness and richest pay zone is against the southern edge of the Waseca channel (Figure 35) where it is between 3m and 4m thick and greater than 5% per weight bitumen. This zone thins to the south where the majority of bitumen concentration is less than 5% (Figure 36). As the pay zone thins the water zone increases towards the edges of the field. This is a structural relationship that is demonstrated by the cross-sections Figures 33 and 34.

The Viking-Kinsella field is one of the few in the Lloydminster area of Alberta that has no direct relationship to the Wainwright Ridge. Its location appears to be caused by a fortuitous coincidence of channel incisement. There may, however, be an indication of structural control in the location of the field area. Figure 38 is a map of the structure of the Sparky B top in the study area. The zero contour which runs through the Viking-Kinsella field shows a pronounced east-west deflection in the field area. This structural low overlies precisely the zero edge of the Lower Lloydminster sand (Figure 13). It was noted earlier that the sharp cutoff at the southern edge of the Lower Lloydminster sand was quite unusual in the Lloydminster area where the gradual attenuation of such sand units is the rule. If the Sparky B structure were a drape feature over the edge of the underlying sandstone it would be a simple monocline quite unlike the closed depression seen here. The coincidence of these two features may indicate a deep-seated control which influenced the location of the Lower Lloydminster sandstone and later, by reactivation, the structure in the Viking-Kinsella field. It is worth noting that there is a third east-west trending element in the Viking-Kinsella field. This is the Waseca channel which lies immediately to the north of the feature. It seems worth considering that the location of this feature could also be influenced by the same deep seated structural control. Such speculation probably can only be

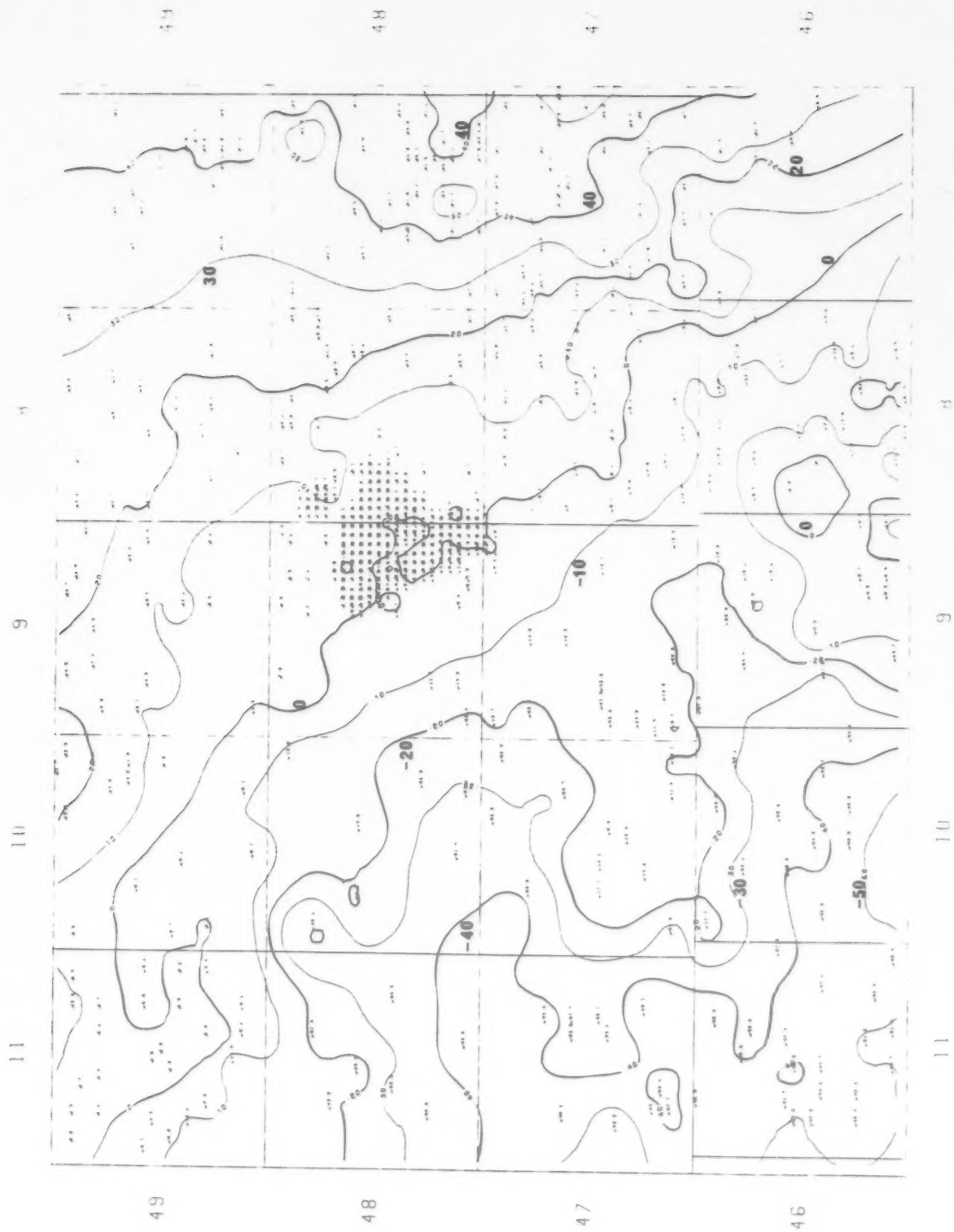


Figure 38 Structure contours at the top of the Sparky B unit. The contour interval is 20 metres. Contour values are relative to present day sea-level.

resolved by seismic investigation.

#### Other Fields

A second oil pool has recently been discovered in the west-central Lloydminster area in township 46 range 10 w4, in sections 27, 28, 33, 34 and 35. All wells are currently confidential. The pay zone is in the Upper Sparky B unit and the gravity of the oil is 23 API. Figure 38 shows that the reservoir is contained within an anticlinal structure. This structure is a drape feature located over an unconformity high that is shown in Figure 5. This once again emphasises the importance of the topography of the sub-Cretaceous unconformity as an exploration target in the Lloydminster area.

## Conclusions

1. The mid Mannville subgroup in west-central Lloydminster contains three broadly defined lithofacies.

Type I. Brackish, tidally-influenced muddy and sandy lagoonal or estuarine deposits.

Type II. Well-sorted, wave-dominated sandstone sheets deposited in a marine shoreface environment.

Type III. Poorly-sorted fluvial and upper estuarine channel sandstones and associated overbank and coastal plain deposits.

2. In west-central Lloydminster the mid Mannville units have the following characteristics:

a. The Lloydminster unit consists of type I brackish bay lithofacies overlain by type II wave dominated shoreface sandstones. The sandstones were deposited on a north-south trending shoreline that prograded to the west during the Lloydminster regression.

b. The RL unit consists of type I estuarine to brackish-bay lithofacies. In the western part of the study area a sandstone body is present that may have been developed on a north-south trending shoreline.

c. The Rex unit is poorly developed throughout the area and does not form a correlatable sandstone unit.

d. The GP forms a regressive sequence from type I estuarine/brackish bay sediments upwards into type III fluvial to coastal plain sediments.

e. The Sparky consists of two transgressive/regressive units; the lower Sparky B consists of type I lithofacies subjected to transgressive reworking and overlain by a thin coastal plain unit; the Upper Sparky B consists of type

I lithofacies overlain by type II shoreline sandstones which are overlain by the Sparky A, consisting of type I lithofacies passing upward into type III coastal plain sediments. The Sparky was deposited on an east-west trending shoreline.

3. Variations between the Mannville sequences on the eastern and western sides of the Wainwright Ridge are due to: (1) Pinching out of lower Mannville and lower mid Mannville units against the sides of the Ridge. (2) Facies changes within upper mid Mannville units overlying the topographically high parts of the Ridge.

4. The Upper Sparky B unit forms the reservoir in the Viking-Kinsella field. This field differs from the majority of Lloydminster fields because its origin is unrelated to the topography of the sub-Cretaceous unconformity. The trapping mechanism is created by the incision of the reservoir unit by opposing mid and upper Mannville channel trends. A second field area is present in the southern part of the study area. This is an Upper Sparky B reservoir that is contained within a drape structure overlying a topographically high area of the sub-Cretaceous unconformity.

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## Appendix 1

Core was examined from the following wells.

Note that most of the GP core included only the top of the unit.

|                |           |                             |
|----------------|-----------|-----------------------------|
| 10-29-46-9 w4  | 2390-2440 | GP Channel, GP, Rex         |
| 15-10-47-10 w4 | 710m-730m | Sparky A, B and GP          |
| 13-10-47-10 w4 | 713m-722m | Sparky A                    |
| 1-18-48-8 w4   | 2274-2305 | RL                          |
| 2b-20-48-8 w4  | 2200-2240 | Sparky A, B and GP          |
| 7d-30-48-8 w4  | 2236-2296 | Sparky B, GP                |
| 11-30-48-8 w4  | 2224-2254 | Sparky B                    |
| 15d-30-48-8 w4 | 2220-2280 | Sparky A, B and GP          |
| 16d 30-48-8 w4 | 2209-2267 | Sparky A, B and GP          |
| 13-30-48-8 w4  | 2258-2313 | Sparky A, B and GP          |
| 10-17-48-8 w4  | 2198-2256 | Sparky B, GP and GP Channel |
| 8-30-48-8 w4   | 2218-2278 | Sparky B, GP                |
| 5-7-48-8 w4    | 2157-2187 | Sparky B, GP                |
| 14d-30-48-8 w4 | 691m-708m | Sparky B, GP                |
| 14a-30-48-8 w4 | 696m-704  | Sparky A, B and GP          |
| 14c-30-48-8 w4 | 686m-704m | Sparky B, GP                |
| 3-17-48-8 w4   | 2167-2197 | Sparky A channel, GP        |
| 12-14-48-9 w4  | 2294-2227 | Sparky B, GP                |
| 10-11-48-9 w4  | 2206-2236 | Sparky B, GP                |
| 13b-23-48-9 w4 | 2117-2177 | Sparky A, B and GP          |
| 10-23-48-9 w4  | 2144-2204 | Sparky A, B and GP          |
| 10-24-48-9 w4  | 2190-2248 | Sparky B, GP                |
| 7-6-49-9 w4    | 2500-2590 | Rex, RL                     |

Outside study area

|               |           |                    |
|---------------|-----------|--------------------|
| 11-23-47-5 w4 | 2115-2168 | Lloydminster       |
| 11-5-46-6 w4  | 674m-688m | Sparky B, GP       |
| 1-10-48-4 w4  | 2187-2247 | Lower Lloydminster |
| 16-7-47-4 w4  | 604m-622m | Lloydminster       |
| 7-21-49-6 w4  | 601m-614m | Sparky B, GP       |
| 6-23-47-5 w4  | 633m-650m | Lloydminster       |
| 10-25-47-3 w4 | 634m-651m | Lloydminster       |

## Appendix 2

The samples were analysed and interpreted by Chaitanya Singh of the Alberta Research Council, with the technical assistance of Bruno Untergasser. A total of eight samples were taken from six wells.

### GP Unit - 1 sample

Well 10-29-46-9 w4 Sampled at 2418 ft., within GP unit below base of Channel. Preservation is moderate, sample is coaly with a moderate plankton diversity.

Cometodinium whitei - abundant

Palaeoperidinium cretaceum - abundant

Tanyosphaeridium salpinx

Muderongia sp.

Pterospermella australiensis

(Acritarch - damaged Mierhystriidium stellatum)

Spores

The environment is interpreted as Brackish/Estuarine.

### Lower Sparky B Unit 3 samples

Well 2B-20-48-8w4. Sampled at 679m.

Preservation moderate, coaly, some plankton present.

Dactulofusa spinata

Acritarchs - Veryhachium reductum and Veryhachium rhomboidium  
Mierhystriidium sp.

The environment is interpreted as slightly brackish.

Well 15d-30-48-8 w4. Sampled at 2263.5 ft.

Preservation moderate, coaly, plankton present

Palaeoperidinium cretaceum

Laciniadinium pusillum

Muderongia sp.

Corroded Peridinioid form

Acritarchs - Mierhystriidium stellatum, Veryhachium reductum

Megaspores - Erlansonisporites sparaosis

The environment is interpreted as brackish/estuarine

Well 16d-30-48-8w4 Sampled at 2260.5 ft.

Preservation moderate, coaly, some plankton present

Cleistosphaeridium multispinosum

Muderongia sp.

Corroded Cyclonesphelium distinctum

The environment is interpreted as slightly brackish.

### Upper Sparky B Unit 4 samples

Well 2b-20-48-8w4 sampled at 673.5m

Preservation moderate, coaly, plankton present.

Cyclonephelium distinctum

Pareodinia sp.

Oligosphaeridium (part of)

Acritarchs - Michystridium stellatum, Veryhachium reductum

Minerisporites

Environment is interpreted as brackish/estuarine.

Well 7d-30-48-8 w4 sampled at 2252 ft.

Preservation moderate, coaly, plankton present

Paleoperidinium cretaceum

Cyclonephelium distinctum

Oligosphaeridium pulcherrimum

Odontochitina operculata

Muderongia sp.

Spiniferites ramosus

Gonyaulacysta sp.

Bacchidium polypes

Cleistosphaeridium multispinosum

Cyclonephelium vannophorum

Acritarchs - Michystridium sp.

The environment is interpreted as nearshore marine

Well 11d-30-48-8 w4 sampled at 2248 ft.

Preservation moderate, coaly, plankton present.

Cyclonephelium distinctum

Baltisphaeridium sp.

Muderongia

Odontochitina operculata

Gonyaulacysta sp.

Acritarchs - Michystridium stellatum, Veryhachium rhomboidium

Environment is interpreted as brackish/estuarine.

Well 15d-30-48-8 w4 sampled at 2254 ft.

Preservation moderate, coaly, plankton present

Oligosphaeridium pulcherrimum

Muderongia

Palaeoperisinium cretaceum

Cyclonephelium distinctum

Gonyaulacysta

Bacchidium polypes

Cleistosphaeridium multisporum

Canningia colliveri

Acritarch - Veryhachium reductum

Spore - Pilosporites verus

Plus Megaspores

Environment interpreted as nearshore marine

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